CHAPTER 200
GEOMETRIC DESIGN AND STRUCTURE STANDARDS

Topic 201 - Sight Distance

Index 201.1 - General

Sight distance is the continuous length of highway ahead visible to the driver. Three types of sight distance are considered here: passing, stopping, and decision. Stopping sight distance is the minimum sight distance to be provided on multilane highways and on 2-lane roads when passing sight distance is not economically obtainable. Stopping sight distance also is to be provided for all elements of interchanges and intersections at grade, including private road connections (see Topic 504, Index 405.1, & Figure 405.7). Decision sight distance is used at major decision points (see Indexes 201.7 and 504.2).

The following table shows the standards for passing and stopping sight distance related to design speed, and these shall be the minimum values used in design.

Table 201.1
Sight Distance Standards

Design Speed[1] (km/h)	Stopping[2] (m)	Passing (m)
30	30	217
40	50	285
50	65	345
60	85	407
70	105	482
80	130	541
90	160	605
100	190	670
110	220	728
120	255	792
130	290	855

(1) See Topic 101 for selection of design speed.
(2) Increase by 20% on sustained downgrades >3% & > 2 km.

Chapter III of "A Policy on Geometric Design of Highways and Streets," AASHTO, 1994, contains a thorough discussion of the derivation of stopping sight distance.

201.2 Passing Sight Distance

Passing sight distance is the minimum sight distance required for the driver of one vehicle to pass another vehicle safely and comfortably. Passing must be accomplished without reducing the speed of an oncoming vehicle traveling at the design speed should it come into view after the overtaking maneuver is started. The sight distance available for passing at any place is the longest distance at which a driver whose eyes are 1070 mm above the pavement surface can see the top of an object 1300 mm high on the road.

Passing sight distance is considered only on 2-lane roads. At critical locations, a stretch of 3- or 4-lane passing section with stopping sight distance is sometimes more economical than two lanes with passing sight distance (see Index 204.4).

Figure 201.2 and Tables 201.2A & B show the relationship among length of vertical curve, design speed, and algebraic difference in grades. Any one factor can be determined when the other two are known.

See Chapter 6 of the Traffic Manual for criteria relating to barrier striping of no-passing zones.

201.3 Stopping Sight Distance

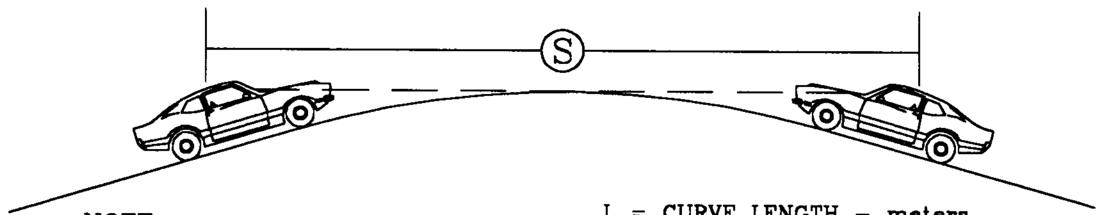
The minimum stopping sight distance is the distance required by the driver of a vehicle, traveling at a given speed, to bring his vehicle to a stop after an object on the road becomes visible. Stopping sight distance is measured from the driver's eyes, which are assumed to be 1070 mm above the pavement surface, to an object 150 mm high on the road.

<u>The stopping sight distances in Table 201.1 should be increased by 20% on sustained downgrades steeper than 3% and longer than 2 km.</u>

Figure 201.2

Passing Sight Distance on Crest Vertical Curves

Height of eye – 1070 mm. . . Height of object – 1300 mm.



NOTE: See Index 204.4 for vertical curve formulas

DESIGN SPEED km/h	PASSING SIGHT DISTANCE m
50	345
60	407
70	482
80	541
90	605
100	670
110	728
120	792
130	855

L = CURVE LENGTH – meters
A = ALGEBRAIC GRADE DIFFERENCE – %
S = SIGHT DISTANCE – meters
V = DESIGN SPEED – km/h FOR "S"

WHEN S > L	WHEN S < L
$L = 2S - \frac{943}{A}$	$L = \frac{AS^2}{943}$

See Table 201.2A (given "A" and "S", find "L") and Table 201.2B (given "A" and "L", find "S") for passing sight distance on crest vertical curves.

Table 201.2A

Passing Sight Distance on Crest Vertical Curves

Given"A" and "S"; Find "L"

Double line represents S=L
L=Curve Length - meters
A=Algebraic grade difference - %
S=Sight distance - meters
V=Design speed - km/h

A (%)	S=230 m V=30 km/h L (m)	S=290 m V=40 km/h L (m)	S=350 m V=50 km/h L (m)	S=425 m V=60 km/h L (m)	S=490 m V=70 km/h L (m)	S=550 m V=80 km/h L (m)	S=605 m V=90 km/h L (m)	S=665 m V=100 km/h L (m)	S=740 m V=110 km/h L (m)	S=790 m V=120 km/h L(m)	S=830 m V=130 km/h L (m)
1.0					37	157	267	387	537	637	717
1.5				221	351	471	581	703	871	993	1096
2.0				379	509	642	776	938	1161	1324	1461
2.5				479	637	802	970	1172	1452	1655	1826
3.0			390	575	764	962	1164	1407	1742	1985	2192
3.5		312	455	670	891	1123	1359	1641	2032	2316	2557
4.0		357	520	766	1018	1283	1553	1876	2323	2647	2922
4.5	252	401	585	862	1146	1444	1747	2110	2613	2978	3287
5.0	280	446	650	958	1273	1604	1941	2345	2903	3309	3653
5.5	309	491	714	1053	1400	1764	2135	2579	3194	3640	4018
6.0	337	535	779	1149	1528	1925	2329	2814	3484	3971	4383
6.5	365	580	844	1245	1655	2085	2523	3048	3775	4302	4749
7.0	393	624	909	1341	1782	2245	2717	3283	4065	4633	5114
7.5	421	669	974	1437	1910	2406	2911	3517	4355	4964	5479
8.0	449	713	1039	1532	2037	2566	3105	3752	4646	5295	5844
8.5	477	758	1104	1628	2164	2727	3299	3986	4936	5626	6210
9.0	505	803	1169	1724	2292	2887	3493	4221	5226	5956	6575
9.5	533	847	1234	1820	2419	3047	3687	4455	5517	6287	6940
10.0	561	892	1299	1915	2546	3208	3881	4690	5807	6618	7305
10.5	589	936	1364	2011	2673	3368	4076	4924	6097	6949	7671
11.0	617	981	1429	2107	2801	3529	4270	5159	6388	7280	8036
11.5	645	1026	1494	2203	2928	3689	4464	5393	6678	7611	8401
12.0	673	1070	1559	2299	3055	3849	4658	5627	6968	7942	8766
12.5	701	1115	1624	2394	3183	4010	4852	5862	7259	8273	9132
13.0	729	1159	1689	2490	3310	4170	5046	6096	7549	8604	9497
13.5	757	1204	1754	2586	3437	4331	5240	6331	7839	8935	9862
14.0	785	1249	1819	2682	3565	4491	5434	6565	8130	9266	10 228
14.5	813	1293	1884	2777	3692	4651	5628	6800	8420	9596	10 593
15.0	841	1338	1949	2873	3819	4812	5822	7034	8710	9927	10 958

Table 201.2B

Passing Sight Distance on Crest Vertical Curves

Given "A" and "L"; Find "S"

Double line represents S=L
L=Curve Length - meters
A=Algebraic grade difference-%
S=Sight distance - meters
V=Design speed - km/h

Refer to Table 201.1 to determine design speed "V", after "S" is determined.

	L=50 m	L=100 m	L=150 m	L=200 m	L=300 m	L=400 m	L=500 m	L=600 m	L=700 m	L=800 m	L=900 m
A (%)	S (m)	S (m)	S (m)	S (m)	S (m)	S (m)	S (m)	S (m)	S (m)	S (m)	S (m)
1.0	497	522	547	572	622	672	722	772	822	872	922
1.5	339	364	389	414	464	514	564	614	663	709	752
2.0	261	286	311	336	386	436	486	532	574	614	651
2.5		239	264	289	339	388	434	476	514	549	583
3.0			232	257	307	355	396	434	469	501	532
3.5				235	284	328	367	402	434	464	492
4.0					266	307	343	376	406	434	461
4.5					251	290	324	355	383	409	434
5.0					238	275	307	336	363	388	412
5.5						262	293	321	346	370	393
6.0						251	280	307	332	355	376
6.5						241	269	295	319	341	361
7.0						232	260	284	307	328	348
7.5							251	275	297	317	336
8.0							243	266	287	307	326
8.5							236	258	279	298	316
9.0								251	271	290	307
9.5								244	264	282	299
10.0								238	257	275	291
10.5								232	251	268	284
11.0									245	262	278
11.5									240	256	272
12.0									235	251	266
12.5										246	261
13.0										241	256
13.5										236	251
14.0										232	246
14.5											242
15.0											238

201.4 Stopping Sight Distance at Grade Crests

Figure 201.4 and Tables 201.4A & B show the relationship among length of vertical curve, design speed, and algebraic difference in grades. Any one factor can be determined when the other two are known.

201.5 Stopping Sight Distance at Grade Sags

From the formulas in Figure 201.5, the minimum length of vertical curve which provides headlight sight distance in grade sags for a given design speed can be obtained. When the stopping sight distance and algebraic grade difference are known, Table 201.5A gives the curve length. When the curve length and algebraic grade difference are known, Table 201.5B gives the sight distance.

If headlight sight distance is not obtainable at grade sags, lighting may be considered. The Project Development Coordinator and the Traffic Liaison Engineer shall be contacted to review proposed grade sag lighting to determine if such use is appropriate.

201.6 Stopping Sight Distance on Horizontal Curves

Where an object off the pavement such as a bridge pier, building, cut slope, or natural growth restricts sight distance, the minimum radius of curvature is determined by the stopping sight distance.

Stopping sight distance on horizontal curves is obtained from Figure 201.6 and Tables 201.6A & B. It is assumed that the driver's eye is 1070 mm above the center of the inside lane (inside with respect to curve) and the object is 150 mm high. The line of sight is assumed to intercept the view obstruction at the midpoint of the sight line and 600 mm above the center of the inside lane. This assumes there is little or no vertical curvature. The clear distance (*m*) is measured from the center of the inside lane to the obstruction. (Note that the clear distance "*m*" is italicized to distinguish it from the "m" used for meters.)

The general problem is to determine the required clear distance from centerline of inside lane to a retaining wall, bridge pier, abutment, cut slope, or other obstruction for a given design speed. Using radius of curvature and sight distance for the design speed, the formula in Figure 201.6 or Table 201.6A gives the clear distance (*m*) from centerline of inside lane to the obstruction.

When the radius of curvature and the clear distance to a fixed obstruction are known, the formula in Figure 201.6 and Table 201.6B gives the sight distance for these conditions.

See Index 101.1 for technical reductions in design speed caused by partial or momentary horizontal sight distance restrictions. See Index 203.2 for additional comments on glare screens.

Cuts may be widened where vegetation restricting horizontal sight distance is expected to grow on finished slopes. Widening is an economic trade-off that must be evaluated along with other options. See Index 902.2 for sight distance requirements on landscape projects.

201.7 Decision Sight Distance

At certain locations, sight distance greater than stopping sight distance is desirable to allow drivers time for decisions without making last minute erratic maneuvers (see Chapter III of "A Policy on Geometric Design of Highways and Streets," AASHTO, 1994).

<u>On freeways and expressways the decision sight distance values in Table 201.7 should be used at lane drops and at off-ramp noses to interchanges, branch connections, roadside rests, vista points, and inspection stations.</u>

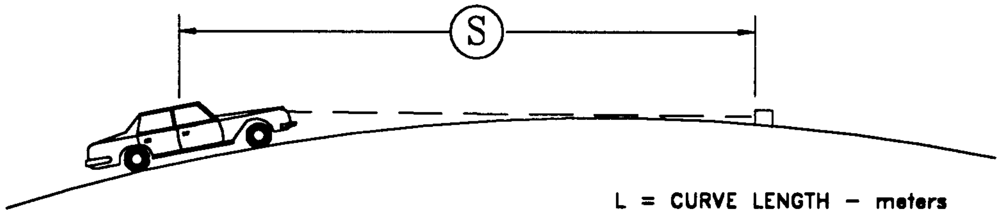
Decision sight distance is measured using the 1070 mm eye height and 150 mm object height. See Index 504.2 for sight distance at secondary exits on a collector-distributor road.

Table 201.7
Decision Sight Distance

Design Speed (km/h)	Decision Sight Distance (m)
100 & under	315
101 - 110	335
111 - 120	375
121 - 130	415

Figure 201.4

Stopping Sight Distance on Crest Vertical Curves



Height of eye – 1070 mm.

Height of object – 150 mm.

L = CURVE LENGTH – meters
A = ALGEBRAIC GRADE DIFFERENCE – %
S = SIGHT DISTANCE – meters
V = DESIGN SPEED – km/h FOR "S"
K = DISTANCE IN METERS REQUIRED TO ACHIEVE A 1% CHANGE IN GRADE. K VALUE AS SHOWN IS VALID WHEN S < L.

WHEN $S > L$
$L = 2S - \frac{405}{A}$

WHEN $S < L$
$L = \frac{AS^2}{405}$

See Table 201.4A (given "A" & "S", find "L") and Table 201.4B (given "A" & "L", find "S") for stopping sight distance on crest vertical curves.

See Figure 204.4 for vertical curve formulas.

See Index 204.4 for minimum length of vertical curve.

Before using this figure for intersections, branch connections and exits, see Indexes 201.7 and 405.1, and Topic 504.

Table 201.4A

Stopping Sight Distance On Crest Vertical Curves

Given "A" and "S"; Find "L"

Double line represents S=L
L = Curve Length -meters
A = Algebraic grade difference - %
S = Sight distance - meters
V = Design speed - km/h
K = Distance in meters required to achieve a 1% change in grade.

A (%)	S=30 m V=30 km/h K=3 m L (m)	S=50 m V=40 km/h K=7 m L (m)	S=65 m V=50 km/h K=11 m L (m)	S=85 m V=60 km/h K=18 m L (m)	S=105 m V=70 km/h K=27 m L (m)	S=130 m V=80 km/h K=42 m L (m)	S=160 m V=90 km/h K=63 m L (m)	S=190 m V=100 km/h K=89 m L (m)	S=220 m V=110 km/h K=120 m L (m)	S=255 m V=120 km/h K=161 m L(m)	S=290 m V=130 km/h K=208 m L (m)
1									35	105	175
1.5							50	110	170	240	311
2					8	58	118	178	239	321	415
2.5				8	48	98	158	223	299	401	519
3				35	75	125	190	267	359	482	623
3.5			14	54	94	146	221	312	418	562	727
4			29	69	109	167	253	357	478	642	831
4.5		10	40	80	123	188	284	401	538	723	934
5		19	49	89	136	209	316	446	598	803	1038
5.5		26	56	98	150	230	348	490	657	883	1142
6		33	63	107	163	250	379	535	717	963	1246
6.5		38	68	116	177	271	411	579	777	1044	1350
7	2	42	73	125	191	292	442	624	837	1124	1454
7.5	6	46	78	134	204	313	474	669	896	1204	1557
8	9	49	83	143	218	334	506	713	956	1284	1661
8.5	12	52	89	152	231	355	537	758	1016	1365	1765
9	15	56	94	161	245	376	569	802	1076	1445	1869
9.5	17	59	99	169	259	396	600	847	1135	1525	1973
10	20	62	104	178	272	417	632	891	1195	1606	2077
10.5	21	65	110	187	286	438	664	936	1255	1686	2180
11	23	68	115	196	299	459	695	980	1315	1766	2284
11.5	25	71	120	205	313	480	727	1025	1374	1846	2388
12	26	74	125	214	327	501	759	1070	1434	1927	2492
12.5	28	77	130	223	340	522	790	1114	1494	2007	2596
13	29	80	136	232	354	542	822	1159	1554	2087	2700
13.5	30	83	141	241	368	563	853	1203	1613	2168	2803
14	31	86	146	250	381	584	885	1248	1673	2248	2907
14.5	32	90	151	259	395	605	917	1292	1733	2328	3011
15	33	93	156	268	408	626	948	1337	1793	2408	3115

Table 201.4B

Stopping Sight Distance On Crest Vertical Curves

Given "A" and "L"; Find "S"

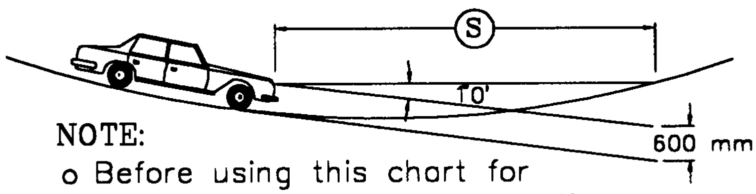
Double line represents S=L
L=Curve Length - meters
A=Algebraic grade difference-%
S=Sight distance - meters
V=Design speed - km/h
K=Distance in meters required to achieve a 1% change in grade.

Refer to Table 201.1 to determine design speed "V", after "S" is determined.

	L=50 m	L=100 m	L=150 m	L=200 m	L=300 m	L=400 m	L=500 m	L=600 m	L=700 m	L=800 m	L=900 m
A (%)	S (m)	S (m)	S (m)	S (m)	S (m)	S (m)	S (m)	S (m)	S (m)	S (m)	S (m)
1			278	303	353	403	450	493	532	569	604
1.5			210	235	285	329	367	402	435	465	493
2			176	201	246	285	318	349	376	402	427
2.5			156	180	220	255	285	312	337	360	382
3			142	164	201	232	260	285	307	329	349
3.5			132	152	186	215	241	263	285	304	323
4			123	142	174	201	225	246	266	285	302
4.5	70	95	116	134	164	190	212	232	251	268	285
5	66	90	110	127	156	180	201	220	238	255	270
5.5	62	86	105	121	149	172	192	210	227	243	257
6	59	82	101	116	142	164	184	201	217	232	246
6.5	56	79	97	112	137	158	177	193	209	223	237
7	54	76	93	108	132	152	170	186	201	215	228
7.5	52	73	90	104	127	147	164	180	194	208	220
8	50	71	87	101	123	142	159	174	188	201	213
8.5	49	69	85	98	120	138	154	169	183	195	207
9	47	67	82	95	116	134	150	164	177	190	201
9.5	46	65	80	92	113	131	146	160	173	185	196
10	45	64	78	90	110	127	142	156	168	180	191
10.5	44	62	76	88	108	124	139	152	164	176	186
11	43	61	74	86	105	121	136	149	161	172	182
11.5	42	59	73	84	103	119	133	145	157	168	178
12	41	58	71	82	101	116	130	142	154	164	174
12.5	40	57	70	80	99	114	127	139	151	161	171
13	39	56	68	79	97	112	125	137	148	158	167
13.5	39	55	67	77	95	110	122	134	145	155	164
14	38	54	66	76	93	108	120	132	142	152	161
14.5	37	53	65	75	92	106	118	129	140	149	159
15	37	52	64	73	90	104	116	127	137	147	156

Figure 201.5

Stopping Sight Distance on Sag Vertical Curves



NOTE:

- o Before using this chart for intersections, branch connections and exits, see Index 201.7, 405.1 and 504.2
- o For sustained downgrades, see Index 201.3.
- o See Figure 204.4 for vertical curve formulas.
- o See Index 204.4 for minimum length of vertical curve.
- o See Table 201.5A (given "A" + "S", find "L") and Table 201.5B (given "A" + "L", find "S") for stopping sight distance on sag vertical curves.

L=CURVE LENGTH – meters
A=ALGEBRAIC GRADE DIFFERENCE – %
S=SIGHT DISTANCE – meters
V=DESIGN SPEED – km/h FOR "S"
K= DISTANCE IN METERS REQUIRED TO ACHIEVE A 1% CHANGE IN GRADE. K VALUE SHOWN IS VALID WHEN S<L.

WHEN S>L
$L=2S-\frac{122+3.5S}{A}$

WHEN S<L
$L=\frac{AS^2}{122+3.5S}$

Table 201.5A

Stopping Sight Distance on Sag Vertical Curves

Given "A" and "S"; Find "L"

Double line represents S=L
L=Curve Length - meters
A=Algebraic grade difference - %
S=Sight distance - meters
V=Design speed - km/h
K=Distance in meters required to achieve a 1% change in grade.

A (%)	S=50 m V=40 km/h K=8 m L (m)	S=65 m V=50 K=12 m L (m)	S=85 m V=60 K=17 m L (m)	S=105 m V=70 K=23 m L (m)	S=130 m V=80 K=29 m L (m)	S=160 m V=90 K=38 m L (m)	S=190 m V=100 K=46 m L (m)	S=220 m V=110 K=54 m L (m)	S=255 m V=120 K=64 m L(m)	S=290 m V=130 K=74 m L (m)
1										
1.5										
2										
2.5					29	47	65	83	104	125
3					68	93	118	143	172	201
3.5				70	95	125	155	185	220	255
4			65	88	116	150	183	217	256	296
4.5			77	101	132	169	206	244	288	333
5		60	86	113	146	188	229	271	320	370
5.5		66	95	124	161	206	252	298	353	407
6		73	103	135	176	225	275	326	385	444
6.5		79	112	146	190	244	298	353	417	481
7		85	121	158	205	263	321	380	449	518
7.5	63	91	129	169	220	282	344	407	481	555
8	67	97	138	180	234	300	367	434	513	592
8.5	72	103	146	191	249	319	390	461	545	629
9	76	109	155	203	264	338	413	488	577	666
9.5	80	115	164	214	278	357	436	515	609	703
10	84	121	172	225	293	375	459	543	641	740
10.5	88	127	181	236	308	394	482	570	673	777
11	93	133	189	248	322	413	505	597	705	814
11.5	97	139	198	259	337	432	528	624	737	851
12	101	145	207	270	351	450	550	651	769	888
12.5	105	151	215	282	366	469	573	678	801	925
13	109	157	224	293	381	488	596	705	833	962
13.5	114	163	233	304	395	507	619	733	865	999
14	118	169	241	315	410	526	642	760	897	1036
14.5	122	175	250	327	425	544	665	787	929	1073
15	126	181	258	338	439	563	688	814	961	1109

Table 201.5B

Stopping Sight Distance on Sag Vertical Curves

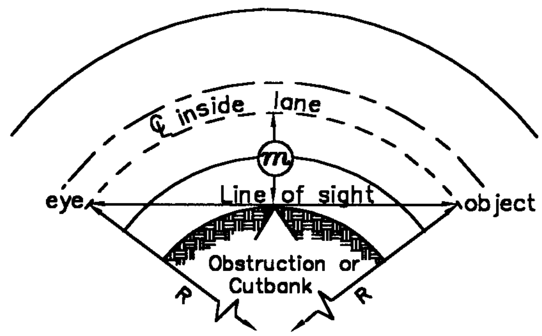
Given "A" and "L"; Find "S"

Double line represents S=L
L=Curve Length - meters
A=Algebraic grade difference - %
S=Sight distance - meters
V=Design speed - km/h
K=Distance in meters required to achieve a 1% change in grade.

	L=50 m	L=100 m	L=150 m	L=200 m	L=300 m	L=400 m	L=500 m	L=600 m	L=700 m	L=800 m	L=900 m
	Refer to Table 201.1 to determine design speed "V", after "S" is determined.										
A (%)	S (m)	S (m)	S (m)	S (m)	S (m)	S (m)	S (m)	S (m)	S (m)	S (m)	S (m)
1.0											
1.5											
2.0	444	644									
2.5	165	248	331	415							
3.0	109	169	229	289							
3.5	85	135	185	235							
4.0	72	116	160	205	294						
4.5	63	104	145	185	264						
5.0	57	96	133	169	240						
5.5	53	89	123	156	221	286					
6.0	50	83	114	145	205	264					
6.5	47	78	107	135	191	246	300				
7.0	45	74	101	127	179	230	281				
7.5	42	70	96	120	169	217	264	311			
8.0	41	67	91	114	160	205	249	294			
8.5	39	64	87	109	152	194	236	278			
9.0	38	61	83	104	145	185	225	264	303		
9.5	36	59	79	99	138	176	214	252	289		
10.0	35	57	76	96	133	169	205	240	276		
10.5	34	55	74	92	127	162	196	230	264	298	
11.0	33	53	71	89	123	156	189	221	253	286	
11.5	32	51	69	86	118	150	181	213	244	274	
12.0	31	50	67	83	114	145	175	205	235	264	294
12.5	30	48	65	80	110	140	169	198	226	255	283
13.0		47	63	78	107	135	163	191	219	246	273
13.5		46	61	76	104	131	158	185	211	238	264
14.0		45	59	74	101	127	153	179	205	230	256
14.5		43	58	72	98	124	149	174	199	223	248
15.0		42	57	70	96	120	145	169	193	217	240

Figure 201.6

Stopping Sight Distance on Horizontal Curves



Line of sight is 600 mm above ℄ inside lane at point of obstruction

S=SIGHT DISTANCE IN METERS.
R=RADIUS OF THE ℄ OF THE LANE NEAREST THE OBSTRUCTION IN METERS.
m=DISTANCE FROM ℄ OF THE LANE NEAREST THE OBSTRUCTION IN METERS.
V=DESIGN SPEED FOR "S" IN km/h.

DESIGN SPEED km/h	SIGHT DISTANCE m
50	65
60	85
70	105
80	130
90	160
100	190
110	220
120	255
130	290

Angle is expressed in degrees.

$$m = R\left[1-\cos\left(\frac{28.65S}{R}\right)\right]$$

$$S = \frac{R}{28.65}\left[\cos^{-1}\left(\frac{R-m}{R}\right)\right]$$

- Formula applies only when "S" is equal to or less than length of curve.
- For sustained downgrades, see index 201.3.

See Table 201.6A (given "R" and "S", find "m") & Table 201.6B (given "R" and "m", find "S") for stopping sight distance on horizontal curves.

Table 201.6A

Stopping Sight Distance on Horizontal Curves

Lateral Clearance to Obstruction
Given "R" and "S"; Find "m"

S=Sight distance - meters
R=Radius of CL of lane - meters
m=Distance from CL of lane - meters
V=Design speed - km/h, for "S"

R (m)	S=30 m V=30 km/h *m* meters	S=50 m V=40 km/h *m* meters	S=65 m V=50 km/h *m* meters	S=85 m V=60 km/h *m* meters	S=105 m V=70 km/h *m* meters	S=130 m V=80 km/h *m* meters	S=160 m V=90 km/h *m* meters	S=190 m V=100 km/h *m* meters	S=220 m V=110 km/h *m* meters	S=255 m V=120 km/h *m* meters	S=290 m V=130 km/h *m* meters
50	2.23	6.12	10.20	17.00	25.12	36.63	51.47	66.17	79.43	91.51	98.55
100		3.11	5.24	8.90	13.47	20.39	30.33	41.84	54.65	70.86	87.96
150		2.08	3.51	5.98	9.10	13.87	20.84	29.10	38.56	51.01	64.80
200		1.56	2.64	4.50	6.85	10.47	15.79	22.14	29.50	39.29	50.31
250			2.11	3.60	5.49	8.40	12.69	17.84	23.82	31.82	40.89
300			1.76	3.01	4.58	7.02	10.61	14.92	19.94	26.69	34.37
400				2.26	3.44	5.27	7.97	11.23	15.03	20.15	26.00
500				1.81	2.75	4.22	6.39	9.00	12.05	16.17	20.88
600				1.50	2.30	3.52	5.33	7.51	10.06	13.50	17.44
700					1.97	3.02	4.57	6.44	8.63	11.58	14.97
800					1.72	2.64	4.00	5.63	7.55	10.14	13.11
900					1.53	2.35	3.55	5.01	6.71	9.02	11.66
1000		*m* is less than 1.5 m				2.11	3.20	4.51	6.04	8.12	10.50
1200						1.76	2.67	3.76	5.04	6.77	8.75
1400						1.51	2.29	3.22	4.32	5.80	7.50
1600							2.00	2.82	3.78	5.08	6.57
1800							1.78	2.51	3.36	4.51	5.84
2000							1.60	2.26	3.02	4.06	5.25
2500								1.81	2.42	3.25	4.20
3000								1.50	2.02	2.71	3.50

Table 201.6B

Stopping Sight Distance on Horizontal Curves

Lateral Clearance to Obstruction

GIVEN "R" AND "m"; FIND "S"

Refer to Table 201.1 to determine design speed "V", after "S" is determined.

S=Sight distance - meters
R=Radius of CL lane - meters
m=Distance from CL lane - meters
V=Design speed - km/h, for "S"

R (m)	*m=* 2 meters S (m)	*m=* 3 meters S (m)	*m=* 4 meters S (m)	*m=* 5 meters S (m)	*m=* 6 meters S (m)	*m=* 7 meters S (m)	*m=* 8 meters S (m)	*m=* 9 meters S (m)	*m=* 10 meters S (m)	*m=* 11 meters S (m)
50	28	35	40	45	49	54	57	61	64	68
100	40	49	57	64	70	75	81	85	90	95
150	49	60	69	78	85	92	98	104	110	116
200	57	69	80	90	98	106	114	120	127	133
250	63	78	90	100	110	119	127	135	142	149
300	69	85	98	110	120	130	139	147	155	163
400	80	98	113	127	139	150	160	170	179	188
500	89	110	127	142	155	168	179	190	200	210
600	98	120	139	155	170	183	196	208	219	230
700	106	130	150	167	183	198	212	225	237	249
800	113	139	160	179	196	212	226	240	253	266
900	120	147	170	190	208	225	240	255	269	282
1000	127	155	179	200	219	237	253	269	283	297
1200	139	170	196	219	240	259	277	294	310	325
1400	150	183	212	237	259	280	299	318	335	351
1600	160	196	226	253	277	299	320	340	358	375
1800	170	208	240	268	294	318	340	360	380	398
2000	179	219	253	283	310	335	358	380	400	420
2500	200	245	283	316	346	374	400	424	447	469
3000	219	268	310	346	380	410	438	465	490	514

Topic 202 - Superelevation

202.1 Basic Criteria

According to the laws of mechanics, when a vehicle travels on a curve it is forced outward by centrifugal force.

On a superelevated highway, this force is resisted by the vehicle weight component parallel to the superelevated surface and side friction between the tires and pavement. It is impractical to balance centrifugal force by superelevation alone, because for any given curve radius a certain superelevation rate is exactly correct for only one driving speed. At all other speeds there will be a side thrust either outward or inward, relative to the curve center, which must be offset by side friction.

If the vehicle is not skidding, these forces are in equilibrium as represented by the following equation, which is used to design a curve for a comfortable operation at a particular speed:

$$\text{Centrifugal factor} = e + f = \frac{0.0079V^2}{R} = \frac{V^2}{127R}$$

Where:

- e = Superelevation slope in meters per meter
- e_{max} = Maximum superelevation rate for a given condition
- f = Side friction factor
- R = Curve radius in meters
- V = Velocity in kilometers per hour

Standard superelevation rates are designed to hold the portion of the centrifugal force that must be taken up by tire friction within allowable limits. Friction factors as related to speed are shown on Figure 203.2. The factors apply equally to portland cement concrete and bituminous pavements.

202.2 Standards for Superelevation

Maximum superelevation rates for various highway conditions are shown on Table 202.2.

Based on an e_{max} selected by the designer for one of the conditions, superelevation rates from Table 202.2 shall be used within the given range of curve radii. If less than standard superelevation rates are approved (see Index 82.1), Figure 203.2 shall be used to determine superelevation based on the curve radius and comfortable speed.

Comfortable speed is determined by the formula given on Figure 203.2. It represents the speed on a curve where discomfort caused by centrifugal force is evident to a driver. Side friction factors tabulated on Figure 203.2 are recommended by AASHTO for design purposes. "A Policy on Geometric Design of Highways and Streets," AASHTO, 1994, states, "In general, studies show that the maximum side friction factors developed between new tires and wet concrete pavements range from about 0.5 at 30 km/h to approximately 0.35 at 100 km/h." The design side friction factors are therefore about one-third the values that occur when side skidding is imminent.

To use Figure 203.2, the designer must decide on the relative importance among three variables. Normally, when a nonstandard superelevation rate is approved, Figure 203.2 will be entered with the rate and a desired curve radius. It must then be determined whether the resulting comfortable speed is adequate for the conditions or whether further adjustments to radius and superelevation may be needed.

Except for short radius curves, the standard superelevation rate results in very little side thrust at speeds less than 75 km/h. This provides maximum comfort for most drivers.

Superelevation for horizontal curves with radii of 3000 m and greater may be deleted in those situations where the combination of a flat grade and a superelevation transition would create undesirable drainage conditions on the pavement.

Superelevated cross slopes on curves extend the full width of the traveled way and shoulders, except that the shoulder slope on the low side should be not less than the minimum shoulder slope used on the tangents (see Index 304.3 for cross slopes under cut widening conditions).

<u>On rural 2-lane roads, superelevation should be on the same plane for the full width of traveled way and shoulders, except on transitions (see Index 304.3 for cut widening conditions).</u>

Table 202.2

Standard Superelevation Rates
(Superelevation in Meters per Meter for Curve Radius in Meters)

For e_{max} = 0.12, 0.10 or 0.08 [(1)]		For e_{max} = 0.06 [(2)]		For e_{max} = 0.04 [(3)]	
Range of Curve Radii	e Rate	Range of Curve Radii	e Rate	Range of Curve Radii	e Rate
190 & Under	0.12	180 & Under	0.06	150 & Under	0.04
191 - 260	0.11	181 - 305	0.05	151 - 305	0.03
261 - 335	0.10	306 - 460	0.04	306 - 1525	0.02
336 - 410	0.09	461 - 610	0.03	Over 1525	(4)
411 - 490	0.08	611 - 2135	0.02		
491 - 580	0.07	Over 2135	(4)		
581 - 670	0.06				
671 - 825	0.05				
826 - 1065	0.04				
1066 - 1370	0.03				
1371 - 6000	0.02				
Over 6000	(4)				

(1) Ramps, 2-lane conventional highways, and 2-lane frontage roads, use e_{max} = 0.12.
For frontage roads under other jurisdictions see Index 202.7.
Freeways, expressways, and multilane conventional highways, use e_{max} = 0.10.
Highways, freeways, and ramps usually above 900 m elevation, where snow and ice conditions prevail, use e_{max} = 0.08.

(2) Urban arterials or frontage roads with design speeds of 55 to 75 km/h, use e_{max} = 0.06.

(3) Urban arterials or frontage roads with design speeds less than 55 km/h, use e_{max} = 0.04.

(4) Use standard crown section. See Index 301.2.

202.3 Restrictive Conditions

Lower superelevation rates than those given in either Table 202.2 or Figure 203.2 may be necessary in areas where restricted speed zones or ramp/street intersections are controlling factors. Other typical locations are short radius curves on ramps near the local road juncture, either at an intersection or where a loop connects with an overcrossing structure. Often, established street grades, curbs, or drainage may prove difficult to alter and/or superelevation transition lengths would be undesirably short.

Such conditions may justify a reduction in the superelevation rate, different rates for each half of the roadbed, or both. In any case, the superelevation rate provided should be appropriate for the conditions allowing for a smooth transition while providing the maximum level of comfort to the driver. Where standard superelevation rates cannot be attained, discussions should be held with the Geometric Reviewer and/or the Project Development Coordinator to determine the proper solution and the necessity of preparing a design exception fact sheet. <u>In warping street or ramp surface areas for drainage, adverse superelevation should be avoided (see Figure 203.2).</u>

202.4 Axis of Rotation

(1) *Undivided Highways.* For undivided highways the axis of rotation for superelevation is usually the centerline of the roadbed. However, in special cases such as desert roads where curves are preceded by long relatively level tangents, the plane of superelevation may be rotated about the inside edge of traveled way to improve perception of the curve. In flat country, drainage pockets caused by superelevation may be avoided by changing the axis of rotation from the centerline to the inside edge of traveled way.

(2) *Ramps and Freeway-to-freeway Connections.* The axis of rotation may be about either edge of traveled way or centerline if multilane. Appearance and drainage considerations should always be taken into account in selection of the axis of rotation.

(3) *Divided Highways.*

(a) Freeways--Where the initial median width is 9 m or less, the axis of rotation should be at the centerline.

Where the initial median width is greater than 9 m and the ultimate median width is 9 m or less, the axis of rotation should be at the centerline, except where the resulting initial median slope would be steeper than 1:10. In the latter case, the axis of rotation should be at the ultimate median edges of traveled way.

Where the ultimate median width is greater than 9 m, the axis of rotation should normally be at the ultimate median edges of traveled way.

To avoid sawtooth on bridges with decked medians, the axis of rotation, if not already on centerline, should be shifted to the centerline.

(b) Conventional Highways--The axis of rotation should be considered on an individual project basis and the most appropriate case for the conditions should be selected.

Aesthetics, grade distortion, superelevation transitions, drainage, and driver perception should be considered when selecting the axis of rotation (see Index 204.2).

202.5 Superelevation Transition

(1) *General.* The superelevation transition generally consists of the crown runoff and the superelevation runoff as shown on Figure 202.5.

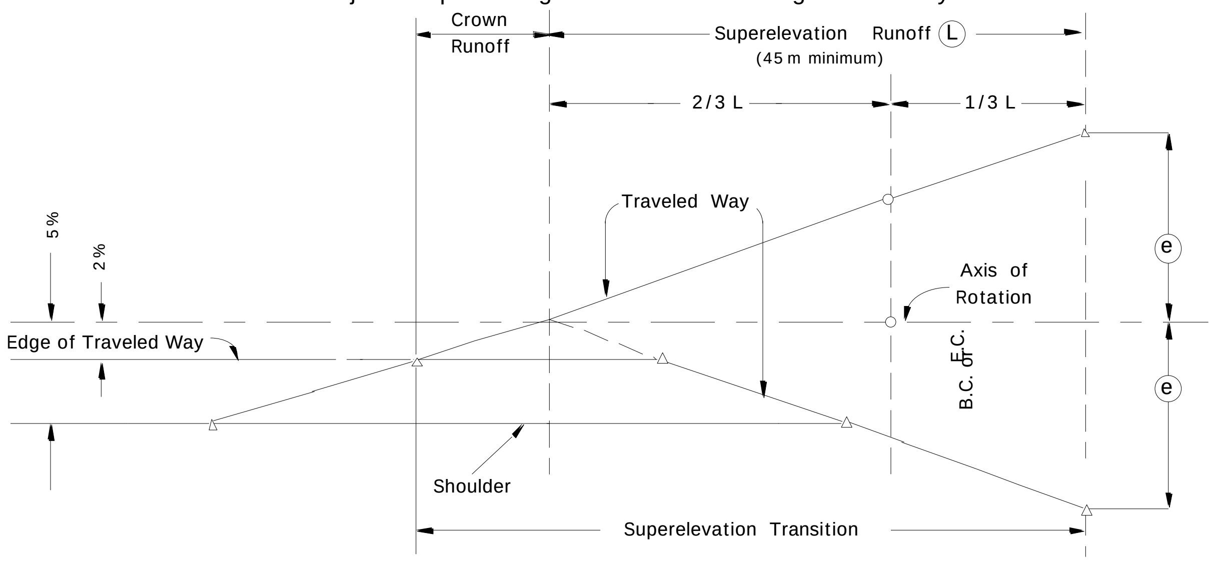
<u>A superelevation transition should be designed in accordance with the diagram and tabular data shown in Figure 202.5 to satisfy the requirements of safety, comfort and pleasing appearance</u>. The length of superelevation transition should be based upon the combination of superelevation rate and width of rotated plane in accordance with the tabulated superelevation runoff lengths on the bottom of Figure 202.5. Transition design may be done either manually or by the recommended IGrds program in the Caltrans CADD (Computer Aided Drafting and Design) system.

Figure 202.5

Superelevation Transition

Formulas		Explanation of Terms
2 Lane Roads	L = 750 e	L = Length of superelevation runoff - m
Multilane Roads & Branch Connections	L = 150 De	e = Superelevation rate - m/m.
Ramps Multilane Single Lane	 L = 750 e if possible L = 600 e	D = Distance from axis of rotation to outside edge of lanes - m
MINIMUM L = 45 m		MAXIMUM L = 153 m

Adjust computed length to nearest meter length divisible by 3



Superelevation Runoff Lengths

Superelevation Rate "e" m/m	2-Lane Highways & Multilane Ramps	Single Lane Ramps	Length, L (meters) — Multilane Highways and Branch Connections with Various "D" Widths: 7.2 m	10.8 m	14.4 m	15.3 m	18 m	18.9 m	22.5 m
0.02	45	45	45	45	45	45	54	57	69
0.03	45	45	45	51	66	69	81	84	102
0.04	45	45	45	66	87	93	108	114	135
0.05	45	45	54	81	108	114	135	141	153
0.06	45	45	66	96	132	138	153	153	
0.07	54	45	78	114	153	153			
0.08	60	48	87	132					
0.09	69	54	99	147					
0.10	75	60	108	153					
0.11	84	66	120						
0.12	90	72	129						

For widths of "D" not included in table, use formula above.

Whichever design method is used, edge of traveled way and shoulder profiles should be plotted and irregularities resulting from interactions between the superelevation transition and vertical alignment of the roadway should be eliminated by introducing smooth curves. Edge of traveled way and shoulder profiles also will reveal flat areas which are undesirable from a drainage standpoint and should be avoided.

(2) *Runoff*. Two-thirds of the superelevation runoff should be on the tangent and one-third within the curve. This results in two-thirds of the full superelevation rate at the beginning or ending of a curve. This may be altered as required to adjust for flat spots or unsightly sags and humps, or when conforming to existing roadway.

(3) *Restrictive Situations.* In restrictive situations, such as on two lane highways in mountainous terrain, interchange ramps, collector roads, frontage roads, etc., where curve radius and length and tangents between curves are short, standard superelevation rates and/or transitions may not be attainable. In such situations the highest possible superelevation rate(s) and transition length should be used, but the rate of change of cross slope should not exceed 4% per 20 m.

(4) *Superelevation Transitions on Bridges.* Superelevation transitions on bridges should be avoided whenever possible (See Index 203.9).

(5) *Shoulder Transitions.* The shoulder plane rotates about the adjacent edge of traveled way as well as the rotational axis of the traveled way. Shoulder superelevation transitions should be smooth and compatible with the transition of the adjacent pavements.

202.6 Superelevation of Compound Curves

Superelevation of compound curves should follow the procedure as shown in Figure 202.6. Where feasible, the criteria in Index 202.5 should apply.

202.7 Superelevation on City Streets and County Roads

Superelevation rates of local streets and roads which are within the State right of way (with or without connection to State facilities) shall conform to AASHTO standards, for the functional classification of the facility in question. If the local agency having jurisdiction over the local facility in question maintains standards that exceed AASHTO standards, then the local agency standards should prevail.

See Index 202.2 and Table 202.2 for Frontage Roads within the State right of way. Frontage roads that will be relinquished after construction should follow AASHTO or local standards as stated above.

Topic 203 - Horizontal Alignment

203.1 General Controls

Horizontal alignment should provide for safe and continuous operation at a uniform design speed for substantial lengths of highway. The standards which follow apply to curvature on both 2-lane and multilane highways except when otherwise noted. These standards also apply to portions of local streets and roads within the State right of way which connect directly to a freeway or expressway, or are expected to do so in the foreseeable future. **For local facilities which are within the State right of way and where there is no connection or the connection is to a non-controlled access facility (conventional highway), AASHTO standards shall prevail**. If the local agency having jurisdiction over the local facility in question maintains standards that exceed AASHTO standards, then the local agency standards should prevail.

The major considerations in horizontal alignment design are safety, profile, type of facility, design speed, geotechnical features, topography, right of way cost and construction cost. In design, safety is always considered, either directly or indirectly. On freeways in metropolitan areas, alternative studies often indicate that right of way considerations influence alignment more than any other

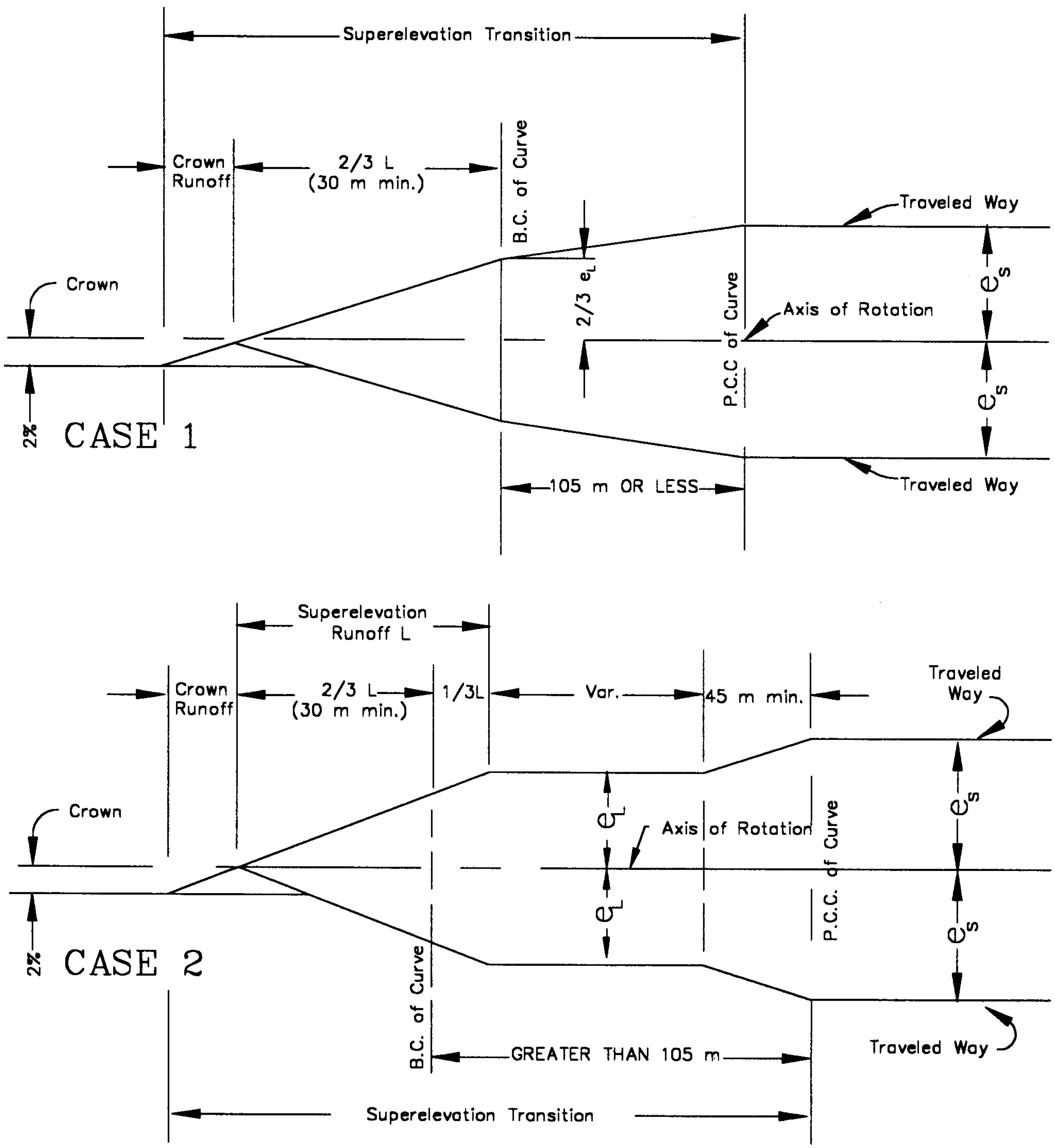
Figure 202.6

Superelevation of Compound Curves

L= Length of superelevation runoff – m

e_s= Superelevation rate for smaller radius curve – m/m or percent

e_L= Superelevation rate for larger radius curve – m/m or percent



single factor. Topography controls both curve radius and design speed to a large extent. The design speed, in turn, controls sight distance, but sight distance must be considered concurrently with topography because it often demands a larger radius than the design speed. All these factors must be balanced to produce an alignment which optimizes the achievement of various objectives such as safety, cost, harmony with the natural contour of the land, and at the same time adequate for the design classification of the highway.

Horizontal alignment shall provide at least the minimum stopping sight distance for the chosen design speed at all points on the highway, as given in Table 201.1 and explained in Index 201.3. See Index 101.1 for technical reductions in design speed.

203.2 Standards for Curvature

Following is a table which gives the minimum radius of curve for specific design speeds. This table is based upon speed alone; it ignores the sight distance factor. If the minimum radius indicated in Table 203.2 does not provide the desired lateral clearance to an obstruction, Figure 201.6 should govern.

Table 203.2

Standards for Curve Radius

Design Speed km/h	Minimum Radius of Curve (m)
30	40
40	70
50	100
60	150
70	200
80	260
90	320
100	400
110	600
120	900
130	1200

Every effort should be made to exceed minimum values, and such minimum radii should be used only when the cost or other adverse effects of realizing a higher standard are inconsistent with the benefits. As an aid to designers, Figure 203.2 displays the comfortable speed for various curve radii and superelevation rates.

The recommended minimum radii for freeways are 1500 m in rural areas and 900 m in urban areas.

If a glare screen or a median barrier is contemplated, either initially or ultimately, adjustments may be necessary to maintain the required sight distance on curves on divided highways. In such cases, a larger curve radius or a wider median may be required throughout the length of the curve. For design purposes, a planting screen is presumed to be 2.4 m wide. See Chapter 7 of the Traffic Manual for glare screen criteria.

203.3 Alignment Consistency

Sudden reductions in alignment standards should be avoided. Where physical restrictions on curve radius cannot be overcome and it becomes necessary to introduce curvature of lower standard than the design speed for the project, the design speed between successive curves should change not more than 15 km/h. Introduction of curves with lower design speeds should be avoided at the end of long tangents, steep downgrades, or at other locations where high approach speeds may be anticipated.

203.4 Curve Length and Central Angle

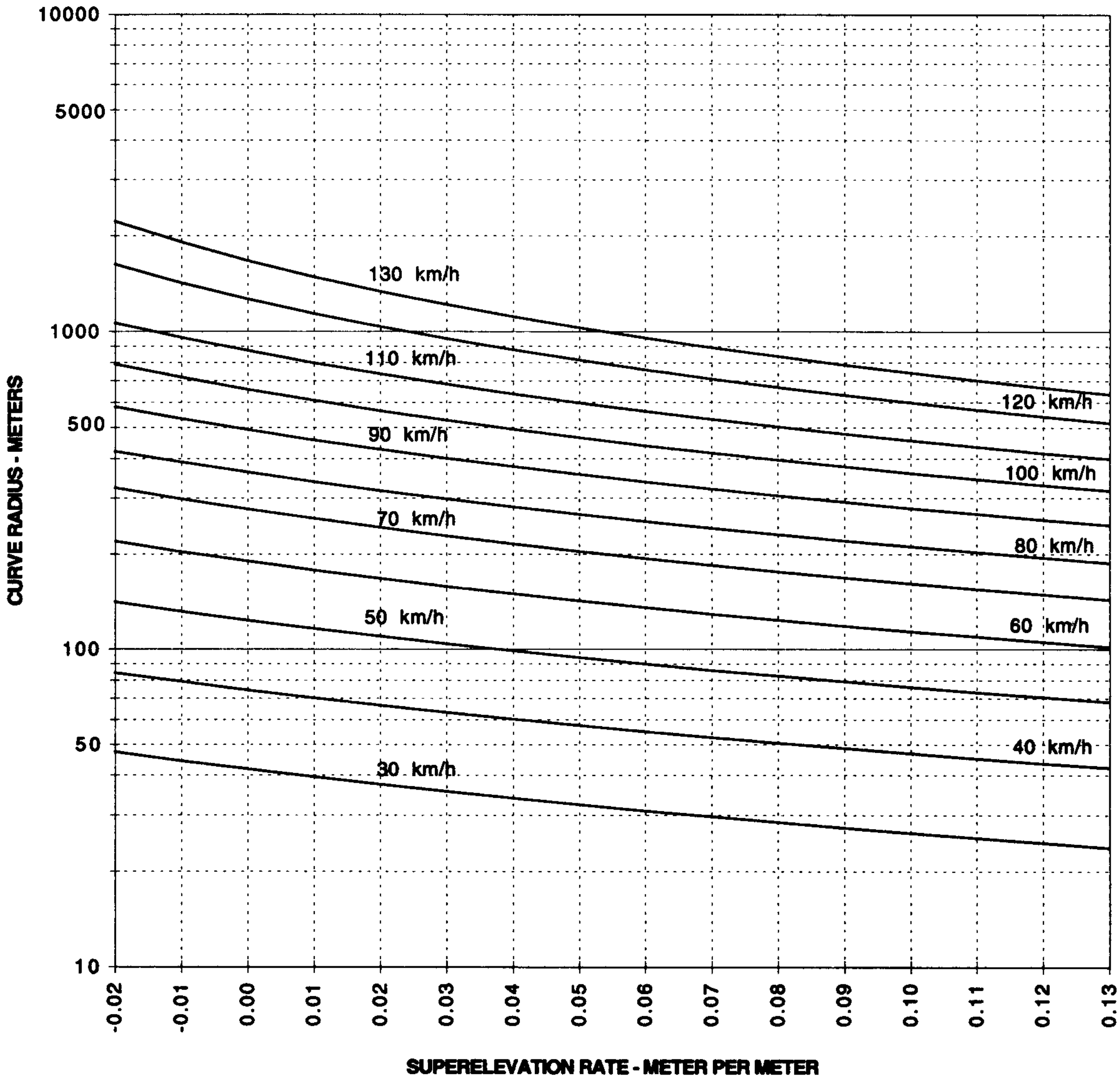
The minimum curve length for central angles less than 10 degrees should be 240 m to avoid the appearance of a kink. For central angles smaller than 30 minutes, no curve is required. Above a 6000 m radius, a parabolic curve may be used. In no event should sight distance or other safety considerations be sacrificed to meet the above requirements.

On 2-lane roads a curve should not exceed a length of 800 m and should be no shorter than 150 m.

203.5 Compound Curves

Compound curves should be avoided, except in mountainous terrain or other situations where

Figure 203.2
Comfortable Speed on Horizontal Curves



Speed (km/h)	Side Friction Factor "f"
30	0.17
40	0.17
50	0.16
60	0.15
70	0.14
80	0.14
90	0.13
100	0.12
110	0.11
120	0.09
130	0.08

NOTES:
This figure is not intended to represent standard superelevation rates or curve radius. The standards are contained in Tables 202.2 and 203.2. This figure should be used as an aid to designers to determine comfortable speeds. Use of this figure in lieu of the standards must be documented as discussed in Index 82.2.

e - Superelevation

f - Side Friction Factor

V - Speed (km/h)

R - Radius (meters)

$$e+f = \frac{0.0079\ V^2}{R}$$

use of a simple curve would result in excessive cost. Where compound curve is necessary, the shorter radius should be at least two-thirds the longer radius when the shorter radius is 300 m or less.

The total arc length of a compound curve should be not less than 150 m.

203.6 Reversing Curves

When horizontal curves reverse direction the connecting tangents should be long enough to accommodate the standard superelevation run-offs given on Figure 202.5. If this is not possible, the 4% per 20 m rate of change should govern (see Index 202.5(3)). When feasible, a minimum of 120 m of tangent should be considered.

203.7 Broken Back Curves

A broken back curve consists of two curves in the same direction joined by a short tangent. Broken back curves are unsightly and undesirable.

203.8 Spiral Transition

Spiral transition curves are not standard practice.

203.9 Alignment at Bridges

Superelevation transitions on bridges almost always result in an unsightly appearance of the bridge and the bridge railing. Therefore, if possible, horizontal curves should begin and end a sufficient distance from the bridge so that no part of the superelevation transition extends onto the bridge. Alignment and safety considerations, however, are paramount and must not be sacrificed to meet the above criteria.

Topic 204 - Grade

204.1 General Controls

The grade line is a reference line by which the elevation of the pavement and other features of the highway are established. It is controlled mainly by topography, type of highway, horizontal alignment, performance of heavy vehicles, right of way costs, safety, sight distance, construction costs, cultural development, drainage, and pleasing appearance.

All portions of the grade line must meet sight distance requirements for the design speed classification of the road.

In flat terrain, the elevation of the grade line is often controlled by drainage considerations. In rolling terrain, some undulation in the grade line is often advantageous for construction economy. But this should be done with appearance in mind; for example, a grade line on tangent alignment exhibiting a series of humps visible for some distance ahead should be avoided whenever possible. In rough country, however, the grade line usually is closely dependent upon physical controls.

In considering alternative profiles, economic comparisons should be made.

The standards in Topic 204 also apply to portions of local streets and roads within the State right of way which connect directly to a freeway or expressway, or are expected to do so in the foreseeable future. **For local facilities which are within the State right of way and where there is no connection or the connection is to a non-controlled access facility (conventional highway), AASHTO standards shall prevail**. If the local agency having jurisdiction over the local facility in question maintains standards that exceed AASHTO standards, then the local agency standards should prevail.

204.2 Position With Respect to Cross Section

The grade line should generally coincide with the axis of rotation for superelevation (see Index 202.4). Its relation to the cross section should be as follows:

(1) *Undivided Highways.* The grade line should coincide with the highway centerline.

(2) *Ramps and Freeway-to-freeway Connections.* The grade line may be positioned at either edge of traveled way or centerline if multilane.

(3) *Divided Highways.* The grade line may be positioned at either the centerline of the median or at the ultimate median edge of traveled way. The former case is

appropriate for paved medians 9 m wide or less. The latter case is appropriate when:

(a) The median edges of traveled way of the two roadways are at equal elevation.

(b) The two roadways are at different elevations (see Index 204.8).

(c) The width of median is nonuniform (see Index 305.6).

204.3 Standards for Grade

Table 204.3 shows the maximum grades which shall not be exceeded for the condition indicated.

Steep grades affect truck speeds and overall capacity. They also cause operational problems at intersections. For these reasons it is desirable to provide the flattest grades practicable (see Index 204.5).

<u>Minimum grades should be 0.5% in snow country and 0.3% at other locations</u>. Except for conventional highways in urban or suburban areas, a level grade line is permissible in level terrain where side fill slopes are 1:4 or flatter and dikes are not needed.

Table 204.3

Maximum Grades for Type of Highway and Terrain Conditions

Type of Terrain	Freeways and Expressways	Rural Highways	Urban Highways
Level	3%	4%	6%
Rolling	4%	5%	7%
Mountainous	6%	7%	9%

<u>Ramp grades should not exceed 8%.</u> On descending on-ramps and ascending off-ramps, 1% steeper is allowed (see Index 504.2(5)).

204.4 Vertical Curves

Properly designed vertical curves should provide adequate sight distance, safety, comfortable driving, good drainage, and pleasing appearance.

A parabolic vertical curve is used. Figure 204.4 gives all necessary mathematical relations for computing a vertical curve, either at crests or sags. <u>For algebraic grade differences of 2% and greater, and design speeds equal to or greater than 60 km/h, the minimum length of vertical curve in meters should be equal to 2V, where V = design speed.</u> As an example, a 100 km/h design speed would require a 200 m minimum vertical curve length. <u>For algebraic grade differences of less than 2%, or design speeds less than 60 km/h, the vertical curve length should be a minimum of 60 m.</u> Vertical curves are not required where the algebraic difference in grades is 0.5% or less. Grade breaks should not be closer together than 15 m and a total of all grade breaks within 60 m should not exceed 0.5%.

Since flat vertical curves may develop poor drainage at the level section, adjusting the gutter grade or shortening the vertical curve may overcome any drainage problems.

On 2-lane roads, extremely long crest vertical curves, over 1 km, should be avoided, since many drivers refuse to pass on such curves despite adequate sight distance. It is sometimes more economical to construct passing lanes than to obtain passing sight distance by the use of a long vertical curve.

Broken-back vertical curves consist of two vertical curves in the same direction separated by a short grade tangent. A profile with such curvature normally should be avoided, particularly in sags where the view of both curves is not pleasing.

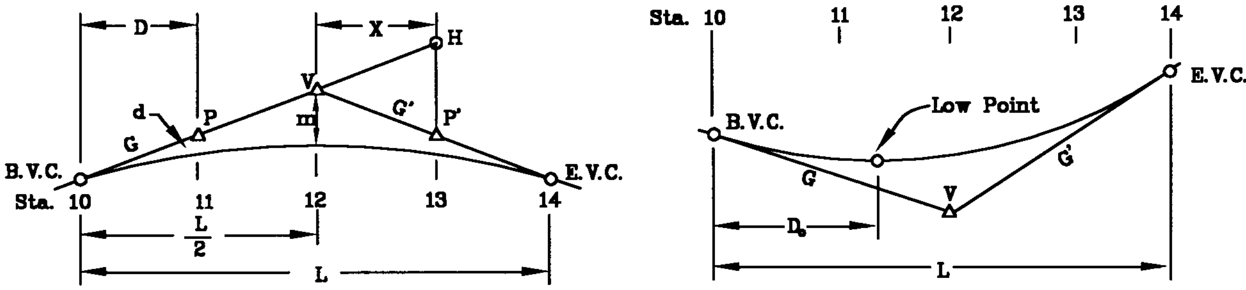
204.5 Sustained Grades

(1) *General.* Maximum grade is not a complete design control. The length of an uphill grade is important as well, because it affects capacity, level of service, and delay when slow moving trucks, buses, and recreational vehicles are present.

A common criterion for all types of highways is to consider the addition of a climbing lane where the running speed of trucks falls 15 km/h or more below the running speed of remaining traffic. Figure 204.5 shows the speed reduction curves for a 180 kg/kW truck, which is representative

Figure 204.4

Vertical Curves



IN ANY VERTICAL CURVE:

(1) $m = \frac{(G'-G)L}{800}$

(2) $m = \frac{1}{2}\left(\frac{El.B.V.C.+El.E.V.C.}{2} - El.V\right)$

(3) $d = m\left(\frac{D}{L/2}\right)^2 = \frac{4m}{L^2}D^2$

(4) $d = \frac{D^2(G'-G)}{L200} = \frac{-D^2}{K200}$

(5) $X = \frac{100(H-P')}{(G'-G)}$

(6) $S = G - D\left(\frac{G-G'}{L}\right) = G - \frac{D}{K}$

(7) $D_0 = \frac{LG}{G-G'}$

(8) $A = G - G'$

(9) $K = \frac{L}{A} = \frac{L}{G-G'}$

WHERE:

L = Length of curve – measured horizontally – meters.

G and G' = Grade rates – percent.

m = Middle ordinate – meters.

d = Correction from grade line to curve – meters

D = Distance from B.V.C. or E.V.C. to any point on curve – meters.

S = Slope of the tangent to the curve at any point – percent.

X = Distance, from P' to V – meters.

H = Elevation of grade G projected to station of P'

P and P' = Elevation on respective grades.

D_0 = Distance to low or high point from extremity of curve – meters.

K = Distance in meters required to achieve a 1% change in grade.

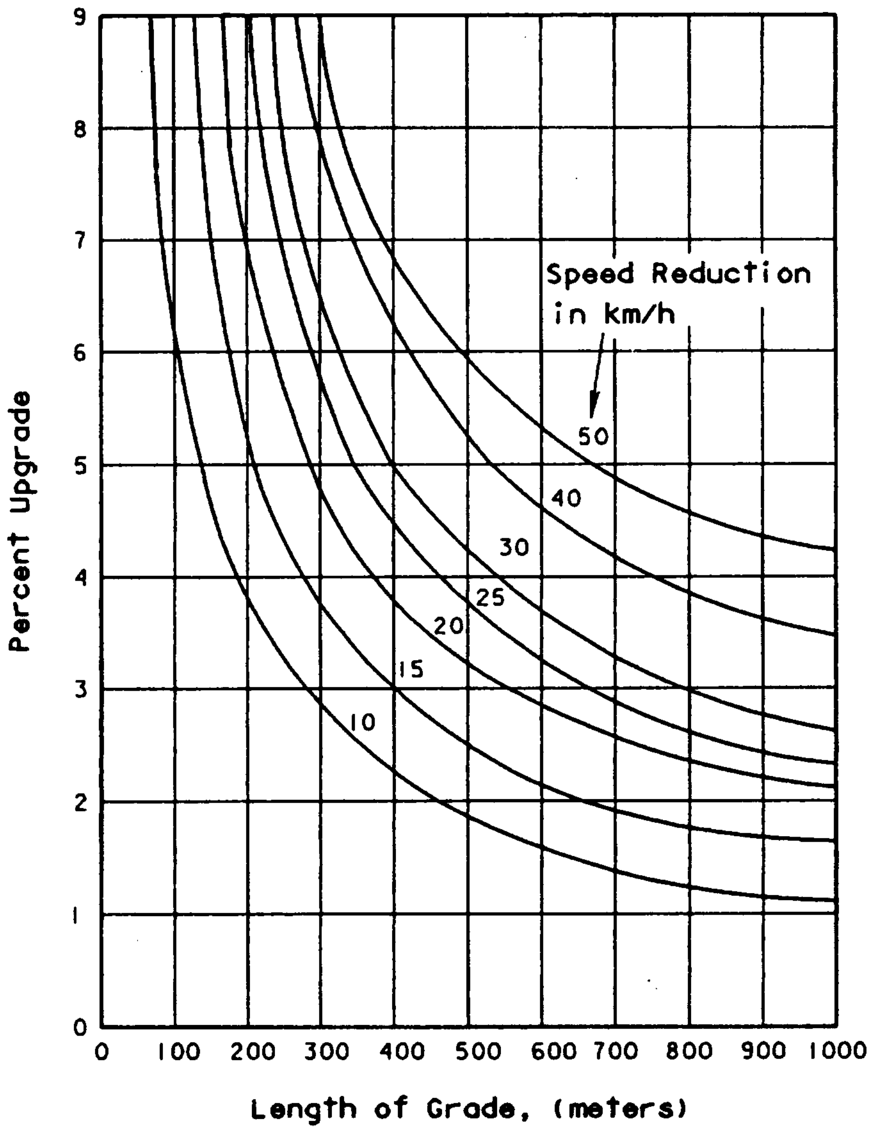
NOTES:

A rising grade carries a plus sign, while a falling grade carries a minus sign.

Thus, in a crest vertical curve as above, G carries a plus sign and G' carries a minus sign when progressing in the direction of the stationing. When progessing in the opposite direction, G becomes a minus grade and G' a plus grade.

Figure 204.5

Critical Lengths of Grade for Design



ASSUMED TYPICAL HEAVY TRUCK OF 180 kg/kW

of large trucks operating near maximum gross weight. The 15 km/h reduction criterion may be used as one method of determining need, however the 1994 Highway Capacity Manual should be consulted for detailed analysis.

(2) *Freeway Climbing Lanes.* If design year traffic volumes are expected to be near capacity, right of way acquisition and grading for a future lane should be considered at locations where the upgrade exceeds 2% and the total rise exceeds 15 m.

Regardless of traffic volumes, the need for a climbing lane should be investigated on sustained upgrades greater than 2% if the total rise is greater than 75 m. Refer to Chapter 3 of the 1994 Highway Capacity Manual for passenger car equivalent factors and sample calculations.

<u>Decision sight distance (Table 201.7) should be provided at climbing lane drops on freeways.</u>

(3) *Two-lane Road Climbing and Passing Lanes.* Climbing and passing lanes are most effective on uphill grades and curving alignment where the speed differential among vehicles is significant. Climbing and passing lanes should normally not be constructed on tangent sections where the length of tangent equals or exceeds the passing sight distance, because passing will occur at such locations without a passing lane and the double barrier stripe increases delay for opposing traffic. Where the ADT exceeds 5000, 4-lane passing sections may be considered.

The Headquarters Traffic Operations Program should be consulted regarding the length of climbing and passing lanes, which will vary with the design speed of the highway, the traffic volume, and other factors.

(4) *Turnouts*

(a) *General.* On a two-lane highway where passing is limited, Section 21656 of the California Vehicle Code requires slow-moving vehicles followed by five or more vehicles to turn off at designated turnouts or wherever sufficient area for a safe turnout exists. Designated turnouts may be constructed in hilly or mountainous terrain or on winding roads in other areas.

(b) *Length.* Designated turnouts should be from 60 to 150 m long including a short taper (usually 15 m) at each end. Approach speeds, grades, traffic volumes, and available space are some factors to be considered in determining the length. The Headquarters Traffic Reviewer should be consulted if longer turnouts are desired.

(c) *Width*. Paved widths of at least 4.5 m in fill sections and 3.6 m in cut sections are recommended. Width is measured from the edge of traveled way. On the outside of curves along steep fill slopes or dropoffs, greater width or the installation of guardrail should be considered.

(d) *Location.* Turnouts should be located where there is stopping sight distance for approaching drivers to see vehicles leaving and re-entering the through lanes.

204.6 Grade Line of Structures

(1) *Structure Depth.* The depth to span ratio for each structure is dependent on many factors. Some of these are: span, type of construction, aesthetics, cost, falsework limitations, and vertical clearance limitations. For purposes of preliminary planning and design, the depth to span ratios listed below may be used in setting grade lines at grade separations.

(a) Railroad Underpass Structures.

- Single track, through girder type structures:use 1.5 m depth from top of rail to structure soffit (bottom of girder).

- Deck-type structures: for simple spans use d/s (depth to span ratio)= 0.08; for continuous multiple span structures use d/s= 0.07. These ratios do not include the additional two feet required above the deck for ballast and rail height).

(b) Highway Structures.

- Structures with single spans of 30 m or less, use d/s= 0.06.
- Structures with single spans between 30 m and 55 m use d/s= 0.045.
- Continuous structures with multiple spans of 30 m or less, use d/s= 0.055.
- Continuous structures with multiple spans of more than 30 m, use d/s= 0.04.

Geometric plans should be submitted to the DOS prior to preparation of the Project Report so that preliminary studies can be prepared. Preliminary bridge type selection should be a joint effort between the DOS and the District.

(2) *Steel or Precast Concrete Structures.* Steel and precast concrete girders in lieu of cast-in-place concrete eliminate falsework, and may permit lower grade lines and reduced approach fill heights. Potential cost savings from elimination of falsework, lowered grade lines, and the ability to accomodate settlement beneath the abutments should be considered in structure type selection along with unit price, aesthetics, uniformity, and any other relevant factors. Note that grade lines at grade separations frequently need to be adjusted after final structure depths are determined (see Index 309.2(3)). Details of traffic handling and stage construction should be provided when the bridge site plan is submitted to the DOS if the design or construction of the structure is affected (see Drafting and Plans Manual, Section 3-3.2).

(3) *Depressed Grade Line Under Structures.* Bridge and drainage design will frequently be simplified if the low point in the grade line is set a sufficient distance from the intersection of the centerlines of the structure and the highway so that drainage structures clear the structure footings.

(4) *Grade Line on Bridge Decks.* Vertical curves on bridge decks should provide a minimum fall of 10 mm per 20 m. This fall should not extend over a length greater than 30 m. The flattest allowable tangent grade should be 0.3%.

(5) *Falsework.* In many cases, it is economically justified to have falsework over traffic during construction in order to have a support-free open area beneath the permanent structure. The elimination of permanent obstructions usually outweighs objections to the temporary inconvenience of falsework during construction.

Because the width of traffic openings through falsework can, and oftentimes does, significantly affect costs, special care should be given to determining opening widths. The following should be considered: staging and traffic handling requirements, the width of approach roadbed that will exist at the time the bridge is constructed, traffic volumes, desires of the local agencies, controls in the form of existing facilities, and the practical problems of falsework construction.

The normal minimum width of traffic openings and required falsework spans for various lane and shoulder combinations should be as shown in Table 204.6.

When temporary K-rail is used to protect the falsework, space must be provided for its deflection. The normal spans shown in Table 204.6 provide 0.6 m for this deflection.

In special cases, where existing constraints make it impractical to comply with the minimum widths of traffic openings set forth in Table 204.6, a lesser width may be approved by the District Director with concurrence from the Headquarters Project Development Coordinator.

The minimum vertical falsework clearance over freeways and nonfreeways shall be 4.6 m. The following items should be considered:

- Mix, volume, and speed of traffic.
- Effect of increased vertical clearance on the grade of adjacent sections.
- Closing local streets to all traffic or trucks only during construction.

- Detours.
- Carrying local traffic through construction on subgrade.
- Temporary or permanent lowering of the existing facility.
- Cost of higher clearance versus cost of traffic control.
- Desires of local agency.

Worker safety should be considered when determining vertical falsework clearance. Requests for approval of temporary vertical clearances less than 4.6 m should discuss the impact on worker safety.

Temporary horizontal clearances less than shown in Table 204.6 or temporary vertical clearances less than 4.6 m should be noted in the PS&E Transmittal Report.

To establish the grade of a structure to be constructed with a falsework opening, allowance must be made for the depth of the falsework. The minimum depths required for various widths of traffic opening are shown in Table 204.6.

Where vertical clearances, either temporary or permanent are critical, the District and the DOS should work in close conjunction during the early design stage when the preliminary grades, structure depths, and falsework depths can be adjusted without incurring major design changes.

Where the vertical falsework clearance is less than 4.6 m, advance warning devices are to be specified or shown on the plans. Such devices may consist of flashing lights, overhead signs, over-height detectors, or a combination of these or other devices.

Warning signs on the cross road or in advance of the previous off-ramp may be required for overheight permit loads. Check with the Regional Permit Manager.

After establishing the opening requirements, a field review of the bridge site should be made by the District designer to ensure that existing facilities (drainage, other bridges, or roadways) will not conflict with the falsework.

The placement and removal of falsework requires special consideration. During these operations, traffic should either be stopped for short intervals or diverted away from the span where the placement or removal operations are being performed. The method of traffic handling during these operations is to be included in the Special Provisions.

204.7 Coordination of Horizontal and Vertical Alignment

A proper balance between curvature and grades should be sought. When possible, vertical curves should be superimposed on horizontal curves. This reduces the number of sight restrictions on the project, makes changes in profile less apparent, particularly in rolling country, and results in a pleasing appearance. Where the change in horizontal alignment at a grade summit is moderate, a pleasing appearance may be attained by making the vertical curve overlap the horizontal curve.

When horizontal and vertical curves are superimposed, the combination of superelevation and profile grades may cause distortion in the outer pavement edges which could confuse drivers at night. In such situations edge of pavement profiles should be plotted and smooth curves introduced to eliminate any irregularities or distortion.

<u>On highways in mountainous or rolling terrain where horizontal and vertical curves are superimposed at a grade summit or sag, the design speed of the horizontal curve should be at least equal to that of the crest or sag, and not more than 15 km/h less than the measured or estimated running (85th percentile) speed of vehicles on the approach roadway</u>.

On long, open curves a uniform grade line should be used because a rolling profile makes for a poor appearance.

Horizontal and vertical curvature at intersections should be as flat as physical conditions permit.

Table 204.6

Falsework Span and Depth Requirements

Facility to be Spanned	Minimum Normal Width of Traffic Opening	Opening Width Provides for	Resulting Falsework Normal Span (1)	Depth of Superstructure (4) Up to 1.85 m	Up to 2.45 m	Up to 3.05 m	Up to 3.65 m
				Minimum Falsework Depth			
Freeway	7.5 m	1 Lane + 2.4 m & 1.5 m Shoulders	10 m	570 mm	635 mm	635 mm	825 mm
	11.1 m	2 Lanes + 2.4 m & 1.5 m Shoulders	13.6 m	840 mm	900 mm	915 mm	990 mm
	14.7 m	3 Lanes + 2.4 m & 1.5 m Shoulders	17.2 m	990 mm	1005 mm	1005 mm	990 mm
	18.3 m	4 Lanes + 2.4 m & 1.5 m Shoulders	20.8 m	1040 mm	1040 mm	1090 mm	1105 mm
Nonfreeway	6 m	1 Lane + 2-1.2 m Shoulders	8.5 m	535 mm	560 mm	560 mm	570 mm
	9.6 m	2 Lanes + 2-1.2 m Shoulders	12.1 m	610 mm	825 mm	840 mm	915 mm
	12 m	2 Lanes + 2-2.4 m Shoulders	14.5 m	915 mm	915 mm	980 mm	990 mm
	15.6 m	3 Lanes + 2-2.4 m Shoulders	18.1 m	990 mm	1005 mm	1005 mm	1015 mm
	19.2 m	4 Lanes + 2-2.4 m Shoulders	21.7 m	1040 mm	1105 mm	1105 mm	1120 mm
Special	6 m	1 Lane + 2-1.2 m Shoulders	6 m (3)	535 mm	560 mm	560 mm	570 mm
Roadways (2)	9.6 m	2 Lanes + 2-1.2 m Shoulders	9.6 m (3)	610 mm	825 mm	840 mm	915 mm

(1) Includes 2.5 m for 2 temporary K-rails and deflection space.
(2) Uses such as fire or utility access or quasi-public roads with very light traffic.
(3) No temporary K-rail provided.
(4) See Index 204.6 for preliminary depth to span ratios. For more detailed information, contact the Division on Structures and refer to the Bridge Design Aids.

204.8 Separate Grade Lines

Separate or independent grade lines are appropriate in some cases for freeways and expressways.

They are not normally considered appropriate where medians are less than 18 m wide (see Index 305.6). Exceptions to this may be minor differences between opposing grade lines in special situations.

In addition, for either interim or ultimate expressways, any appreciable grade differential between roadbeds should be avoided in the vicinity of at-grade intersections. For traffic entering from the crossroad, confusion and wrong-way movements could result if the pavement of the far roadway is obscured because of excessive differential.

Topic 205 - Road Connections and Driveways

205.1 Access Openings on Expressways

Access openings are used only on expressways. The term access opening applies to openings through the right of way line which serve abutting land ownerships whose remaining access rights have been acquired by the State.

(1) *Criteria for Location.* To discourage wrong-way movements, access openings should be located directly opposite or at least 100 m from a median opening. The access opening should not be spaced closer than 1 km to an adjacent public road intersection or to another private access opening that is wider than 10 m.

Sight distance equivalent to that required for public road intersections shall be provided (see Index 405.1).

(2) *Width.* The normal access opening width should be 10 m. A greater width may result in large savings in right of way costs in some instances, but should be considered with caution because of the possibility that public use might develop. Conversion of a private opening into a public road connection requires the consent of the CTC, which cannot be committed in advance (see the Project Development Procedures Manual).

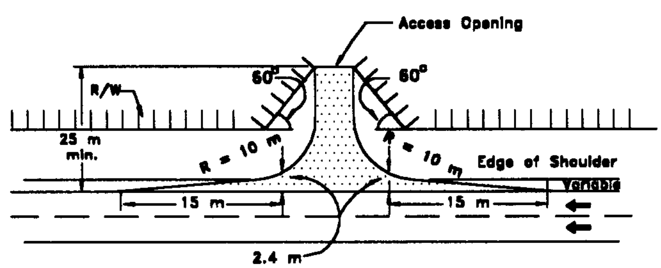
(3) *Recessed Openings.* Recessed openings, as shown on Figure 205.1, are desirable at all points where private access is permitted and should be provided whenever they can be obtained without requiring alterations to existing adjacent improvements. When recessed openings are required, the opening should be located a minimum distance of 25 m from the nearest edge of the traveled way.

(4) *Joint Openings.* A joint access opening serving two or more parcels of land is desirable whenever feasible. If the property line is not normal to the right of way line, care should be taken in designing the joint opening so that both owners are adequately served.

(5) *Surfacing.* All points of private access should be surfaced with adequate width and depth of pavement to serve the anticipated traffic. The surfacing should extend from the edge of the traveled way to the right of way line.

Figure 205.1

Access Openings on Expressways



RECESSED OPENING

NOTES:

- By widening the expressway shoulder, deceleration lanes may be provided where justified.
- This detail, without the recess, may be used on conventional highways.

205.2 Private Road Connections

The minimum private road connection design is shown on Figure 205.1. Sight distance requirements for the minimum private road connection are shown on Figure 405.7 (see Index 405.1).

205.3 Urban Driveways

These instructions apply to the design of driveways to serve property abutting on State highways in cities or where urban type development is encountered.

For driveways on frontage roads and in rural areas see Index 205.4. Details for driveway construction are shown on the Standard Plans. For corner sight distance, see Index 405.1(2)(c).

(1) *Correlation with Local Standards.* Where there is a local requirement regulating driveway construction, the higher standard will normally govern.

(2) *Driveway Width.* The width of driveways for both residential and commercial usage is measured along the gutter line between the toe of the side slopes.

(3) *Residential Driveways.* The width of single residential driveways should be 3.6 m minimum and 6 m maximum. The width of a double residential driveway such as used for multiple dwellings should be 6 m minimum and 10 m maximum. The width selected should be based on an analysis of the anticipated volume, type and speed of traffic, location of buildings and garages, width of street, etc.

(4) *Commercial Driveways.* Commercial driveways should be limited to the following maximum widths:

   (a) When the driveway is used for one-way traffic, the maximum width should be 8 m. If the driveway serves a large parcel, where large volumes of vehicles or large vehicles are expected, the entrance maximum width should be 12 m and the exit maximum width should be 10 m.

   (b) When the driveway is used for two-way traffic, the maximum width should be 10 m. If the driveway serves a large parcel, where large volumes of vehicles or large vehicles are expected, then the maximum width should be 15 m.

   (c) When only one driveway serves a given property, in no case should the width of the driveway including the side slope distances exceed the property frontage.

   (d) When more than one driveway is to serve a given property, the total width of all driveways should not exceed 70 percent of the frontage where such a frontage is 30 m or less. Where the frontage is more than 30 m, the total driveway width should not exceed 60 percent of the frontage. In either case, the width of the individual driveway should not exceed those given in the preceding paragraphs. Where more than one driveway is necessary to serve any one property, not less than 6 m of full height curb should be provided between driveways. This distance between driveways also applies to projects where curbs and gutters are not to be placed.

   (e) Certain urban commercial driveways may need to accommodate the maximum legal vehicle. The width will be determined by the use of truck turn templates.

(5) *Surfacing.* Where curbs, gutters, and sidewalks are to be placed, driveways should be constructed of portland cement concrete. Where only curbs and gutters are to be placed and pedestrian traffic or adjacent improvements do not warrant concrete driveway construction, the driveway may be paved with the same materials used for existing surfacing on the property to be served.

(6) *Pedestrian and Disabled Persons Access.* Where sidewalks traverse driveways, accessibility regulations require that a relatively level (2% max. cross fall) path, at least 1.22 m wide, is provided. Provision of this feature, as indicated in the Standard Plans, may require the acquisition of a construction easement or additional right of way. Assessment of these needs must be

performed early enough in the design to allow time for acquiring any necessary permits or right of way. Additionally, designers should consider the following:

- Where restricted parking zones have been established (either blue or white painted zones) adjacent to driveways, but no reasonably close ramp access to the sidewalk exists, consideration should be given to reducing the maximum slope of the driveway from 10% to 8.33% to provide sidewalk access to the disabled.

- In many cases providing the pathway along the back of the driveway will lower the elevation at the back of the sidewalk. Depending on grades behind the sidewalk the potential may exist for roadway generated runoff to enter private property. The need for features such as low berms within the construction easement, or installation of catch basins upstream of the driveway should be determined.

When pedestrian activity is neither present, nor expected to be present within the reasonable future, the designer may develop driveway details that eliminate the flatter portion along the back edge in lieu of using the Standard Plans for driveways. Refer to Topic 105 for additional information related to pedestrian facilities.

205.4 Driveways on Frontage Roads and in Rural Areas

On frontage roads and in rural areas where the maximum legal vehicle must be accommodated, standard truck-turn templates should be used to determine driveway widths where the curb or edge of traveled way is so close to the right of way line that a usable connection cannot be provided within the standard limits.

Where county or city regulations differ from the State's, it may be desirable to follow their regulations, particularly where jurisdiction of the frontage road will ultimately be in their hands.

205.5 Financial Responsibility

Reconstructing or relocating any access openings, private road connections, or driveways required by revisions to the State highway facility should be done at State expense by the State or its agents. Reconstruction or relocation requested by others should be paid for by the requesting party.

Topic 206 - Pavement Transitions

206.1 General Transition Standards

Pavement transition and detour standards should be consistent with the section having the highest design standards. The transition should be made on a tangent section whenever possible and should avoid locations with horizontal and vertical sight distance restrictions. Whenever feasible, the entire transition should be visible to the driver of a vehicle approaching the narrower section. The design should be such that intersections at grade within the transition area are avoided. For decision sight distance at lane drops, see Index 201.7.

206.2 Pavement Widenings

(1) Through Lane Additions. Where through lanes, climbing lanes, or passing lanes are added, the minimum recommended distance over which to transition traffic onto the additional width is 75 m per lane. Figure 206.2 shows several examples of acceptable methods for adding a lane in each direction to a two-lane highway.

(2) Turning, Ramp, and Speed Change Lanes. Transitions for lane additions, either for left or right turns or to add a lane to a ramp, should typically occur over a length of 35 m. Lengths shorter than 35 m are acceptable where design speeds are below 75 km/h or for conditions as stated in Index 405.2(2)(c).

Where insufficient median width is available to provide for left turn lanes, through traffic will have to be shifted to the outside. See Figures 405.2A, B and C for acceptable methods of widening pavement to provide for median turn lanes.

(3) *Lane Widening.* An increase in lane width can occur at short radius curves which are widened for truck off-tracking, at ramp terminals with large truck turning volumes, or when new construction matches existing roadways with narrow lane widths. Extensive transition lengths are not necessary as the widening does not restrict the drivers expectations. Transition tapers for these types of situations should be at 10:1.

(4) *Shoulder Widening.* Shoulder widening should normally be accomplished in a manner that provides a smooth transition, but can be accomplished without a taper if necessary.

206.3 Pavement Reductions

(1) *Through Lane Drops.* When a lane is to be dropped, it should be done by tapering over a distance equal to 2/3WV, where W = Width of lane to be dropped and V = Design Speed. In general, the transition should be on the right so that traffic merges to the left. Figure 206.2 provides several examples of acceptable lane drops at 4-lane to 2-lane transitions. The exception to using the 2/3WV criteria is for the lane drop/freeway merge movement on a branch connection which is accomplished using a 50:1 taper.

(2) *Ramp and Speed Change Lanes.* As shown in Figures 504.2A and 504.3C, the standard taper for a ramp merge into a through traffic lane is 50:1. Where ramp lanes are dropped prior to the merge with the through facility, the recommended taper is 50:1 for design speeds over 75 km/h, and the taper distance should be equal to 2/3 WV for speeds below 75 km/h.

The "Ramp Meter Design Guidelines" also provide information on recommended and minimum tapers for ramp lane merges. These guideline values are typically used in retrofit or restricted right-of-way situations, and are acceptable for the specific conditions stated in the guidelines.

Figure 405.9 shows the standard taper to be used for dropping an acceleration lane at a signalized intersection. This taper can also be used when transitioning median acceleration lanes.

Figures 405.2A, B and C show the recommended methods of transitioning pavement back into the median area on conventional highways after the elimination of left turn lanes.

(3) *Lane Reductions.* At any location where lane widths are being reduced, the minimum length over which to accomplish the transition should be equal to 2/3WV. See Index 504.6 for mainline lane reductions at interchanges.

(4) *Shoulder Reduction.* Shoulder reductions should typically occur over a length equal to WV/2. However, when shoulder widths are being reduced in conjunction with a lane addition or widening (as in Alt. A of Figure 504.3B), the shoulder reduction should be accomplished over the same distance as the addition or widening.

206.4 Temporary Freeway Transitions

It is highly desirable that the design standards for a temporary transition between the end of a freeway construction unit and an existing highway should not change abruptly from the freeway standards. Temporary freeway transitions must be reviewed by the Project Development Coordinator.

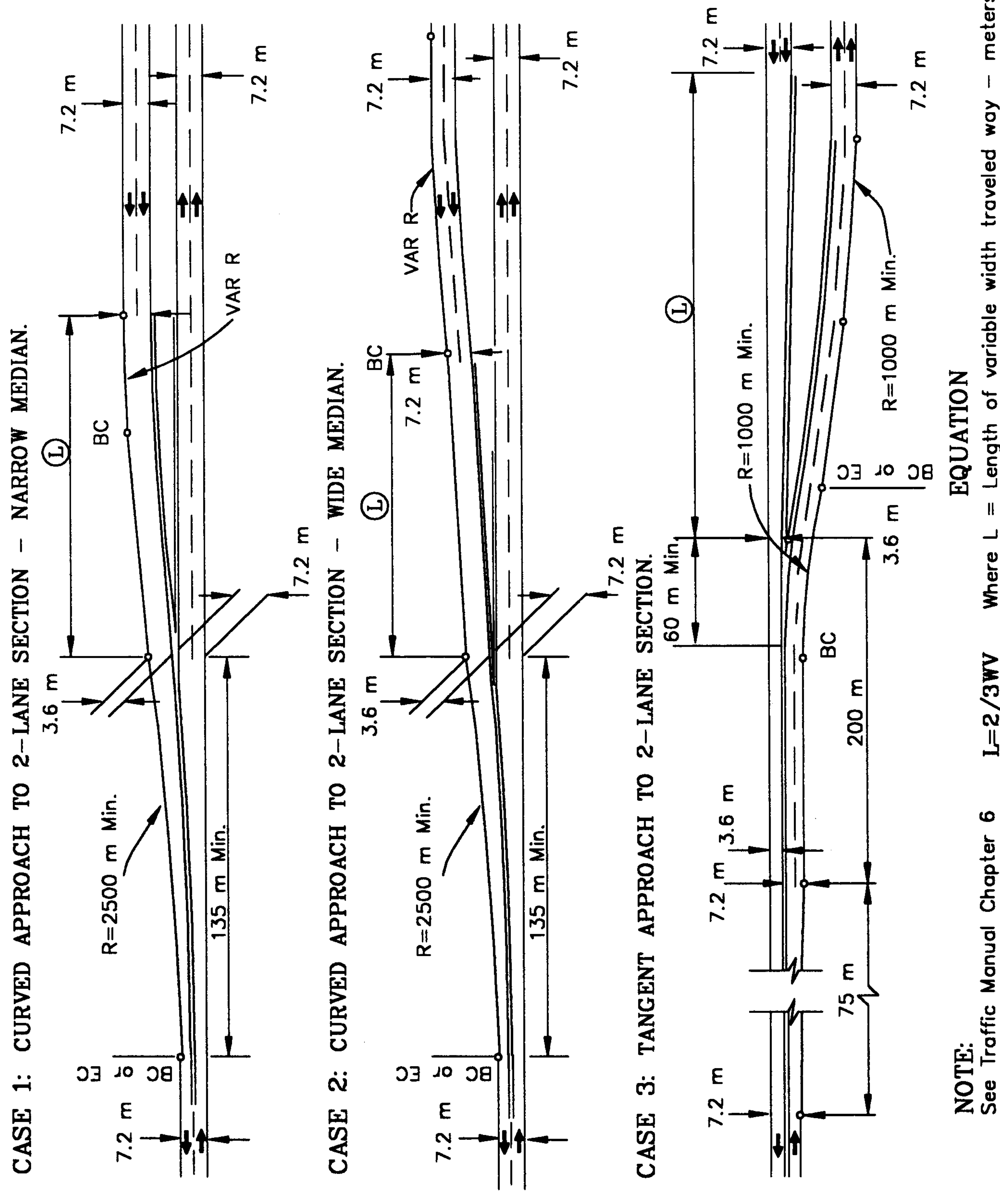
Topic 207 - Airway-Highway Clearances

207.1 Introduction

(1) *Objects Affecting Navigable Airspace.* An object is considered an obstruction to air navigation if any portion of that object is of a height greater than the approach and transverse surfaces extending outward and upward from the airport runway. These objects include overhead signs, light standards, moving vehicles on the highway and overcrossing structures, and equipment used during construction.

(2) *Reference.* The FAA has published regulations relative to clearance entitled, "Part 77, Federal Aviation Regulations" dated January, 1975. This is an approved reference to be used in conjunction with this manual.

Figure 206.2
Typical Two-lane to Four-lane Transitions



207.2 Clearances

(a) Civil Airports--See Figure 207.2A.

(b) Heliports--See Figure 207.2B.

(c) Military Airports--See Figure 207.2C.

(d) Navy Carrier Landing Practice Fields--See Figure 207.2D.

207.3 Submittal of Airway-Highway Clearance Data

The following procedure must be observed in connection with airway-highway clearances in the vicinity of airports and heliports.

Notice to the FAA is required when highway construction is planned near an airport (civil or military) or a heliport. A "Notice of Proposed Construction or Alteration" should be submitted to the FAA Administrator when required under criteria listed in Paragraph 77.13 of the latest Federal Aviation Regulations, Part 77. Such notice should be given as soon as highway alignment and grade are firmly established. It should be noted that these requirements apply to both permanent objects and construction equipment. When required, four copies of the Notice, Form FAA-7460-1 and accompanying maps must be sent to the Chief, Air Traffic Branch, Federal Aviation Administration, Western Regional Office, P.O. Box 92007, Worldway Postal Center, Los Angeles, CA. 90009. Copies of Form FAA-7460-1 may be obtained from the Western Regional Office.

The maps accompanying these notices should contain the following minimum information.

- Distance from project to runway.
- Elevation of runway.
- Relationship between airport runway and highway elevations, including elevations of objects, such as, overhead lights and signs.

The international language for flight is English units. Therefore, all communication with the FAA, including all mapping, must be in English units, not metric.

One copy of form FAA-7460-1 should be forwarded to the Office of Project Planning and Design and one copy to the Division of Aeronautics for information.

Topic 208 - Bridges and Grade Separation Structures

208.1 Bridge Width

(1) State Highways. **The clear width of all bridges, including grade separation structures, shall equal the full width of the traveled way and paved shoulders on the approaches with the following exceptions:**

(a) Bridges to be constructed as replacements on existing 2-lane, 2-way roads shall not have less than a 9.6 m wide roadbed. (see Index 307.2).

(b) When the approach shoulder width is less than 1.2 m, the minimum offset on each side shall be 1.2 m.

The width should be measured normal to the center line between faces of curb or railing measured at the gutter line. For offsets to safety shape barriers see Figure 208.1.

For horizontal and vertical clearances, see Topic 309.

(2) Roads Under Other Jurisdictions.

(a) Overcrossing Widths--(See Index 308.1.)

(b) Undercrossing Span Lengths--Initial construction should provide for the ultimate requirements. In areas where the local jurisdiction has a definite plan of development, the ultimate right of way width or at least that portion needed for the roadbed and sidewalks should be spanned.

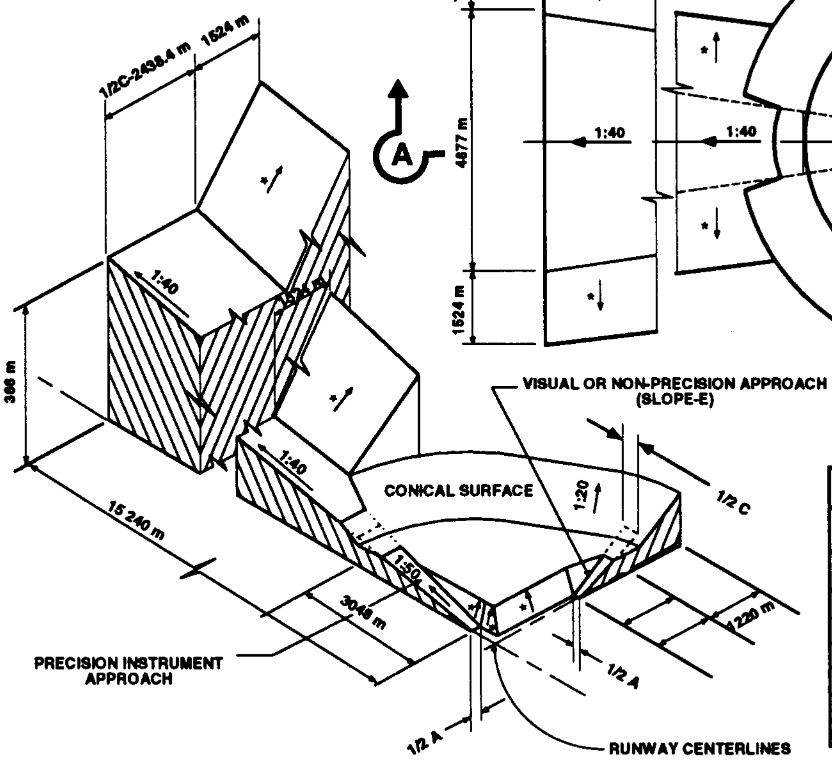
If the undercrossing street or road has no median, one should be provided where necessary to accommodate left-turn lanes or the center piers of the undercrossing structure.

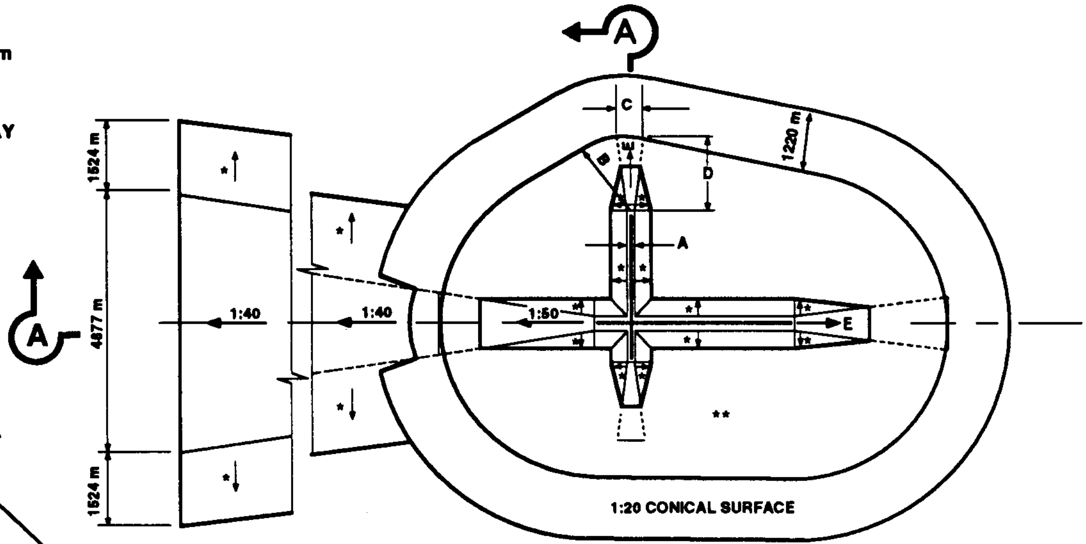
Figure 207.2A
Airway-Highway Clearance Requirements (Civil Airports)

* 1:7

** HORIZONTAL SURFACE 46 m ABOVE ESTABLISHED AIRPORT ELEVATION

*** 5.1 m INTERSTATE HIGHWAY
4.5 m PUBLIC ROAD
3.0 m PRIVATE ROAD





ISOMETRIC VIEW OF SECTION A-A

RUNWAY STANDARDS							
TYPES OF RUNWAY		VISUAL RUNWAY		NON-PRECISION INSTRUMENT RUNWAY			PRECISION INSTRUMENT RUNWAY
		I	II	I	II		
					III	IV	
DIM	ITEM	DIMENSIONAL STANDARDS (METERS)					
A	*****	77	153	153	153	305	305
B	RADIUS OF HORIZONTAL SURFACE	1524	1524	1524	3048	3048	3048
C	APPROACH SURFACE WIDTH AT END	381	458	610	1067	1220	4877
D	APPROACH SURFACE LENGTH	1524	1524	1524	3048	3048	☆
E	APPROACH SLOPE	1:20	1:20	1:20	1:34	1:34	☆

***** WIDTH OF PRIMARY SURFACE AND APPROACH SURFACE WIDTH AT INNER END

I UTILITY RUNWAY
II RUNWAYS LARGER THAN UTILITY
III VISIBILITY MINIMUMS GREATER THAN 1207 m
IV VISIBILITY MINIMUMS AS LOW AS 1207 m
☆ PRECISION INSTRUMENT APPROACH SLOPE IS 1:50 FOR INNER 3048 m AND 1:40 FOR AN ADDITIONAL 12 192 m

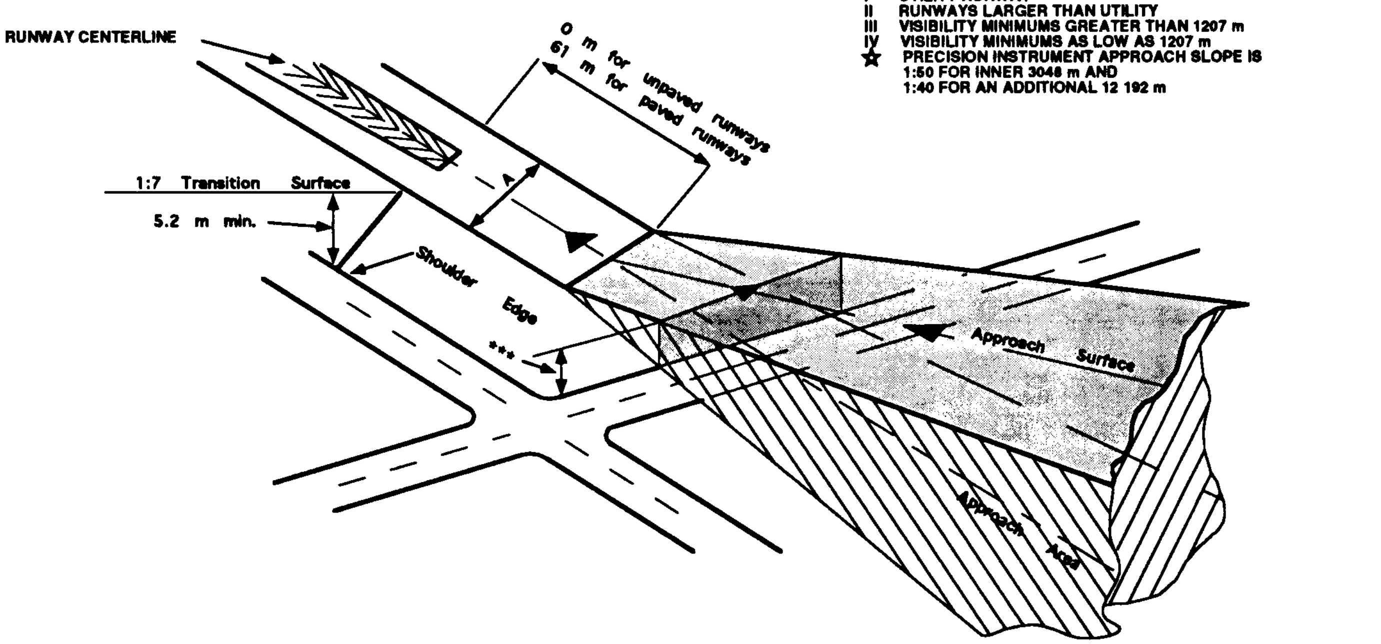


Figure 207.2B

Airway-Highway Clearance Requirements (Heliport)

NOTES:

1. ALL DIMENSIONS IN METERS.
2. DIMENSIONS "a" AND "b" ARE THE SAME AND ARE EQUAL TO ONE AND ONE-HALF TIMES THE OVERALL HELICOPTER LENGTH.
3. MINIMUM VERTICAL CLEARANCE IS 5.1 m FOR INTERSTATE HIGHWAYS, 4.6 m FOR PUBLIC ROADS, AND 3.0 m FOR PRIVATE ROADS.

HIGHWAY CLEARANCE: PROFILE AT PAVEMENT EDGE NEAR AIRFIELD.

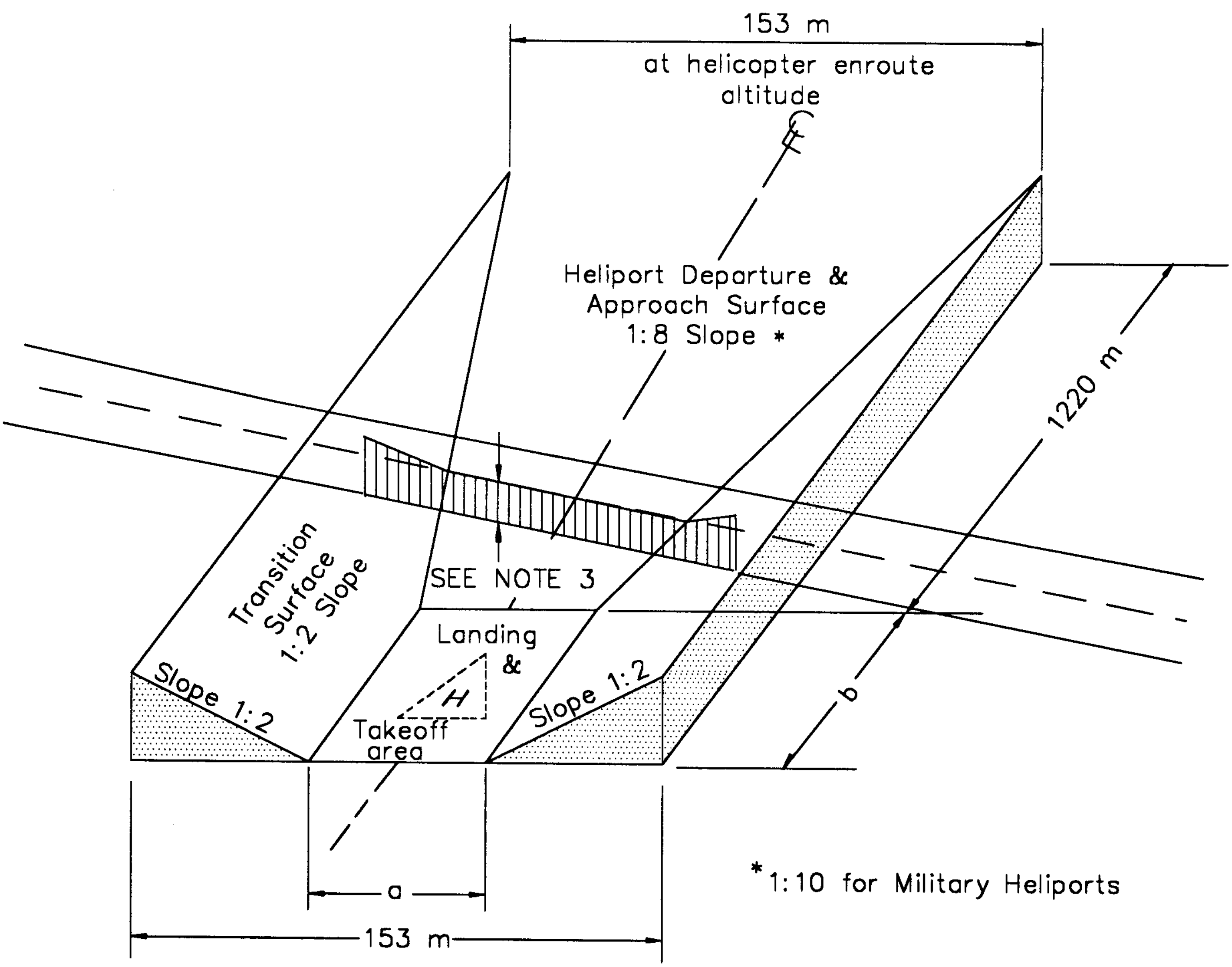


Figure 207.2C

Airway-Highway Clearance Requirements (Military Airports)

LEGEND

A- PRIMARY SURFACE
B- CLEAR ZONE SURFACE
C- APPROACH - DEPARTURE CLEARANCE SURFACE (GLIDE ANGLE) - 1:50
D- APPROACH - DEPARTURE CLEARANCE SURFACE (HORIZONTAL)
E- INNER HORIZONTAL SURFACE
F- CONICAL SURFACE - 1:20
G- OUTER HORIZONTAL SURFACE
H- TRANSITIONAL SURFACE - 1:7

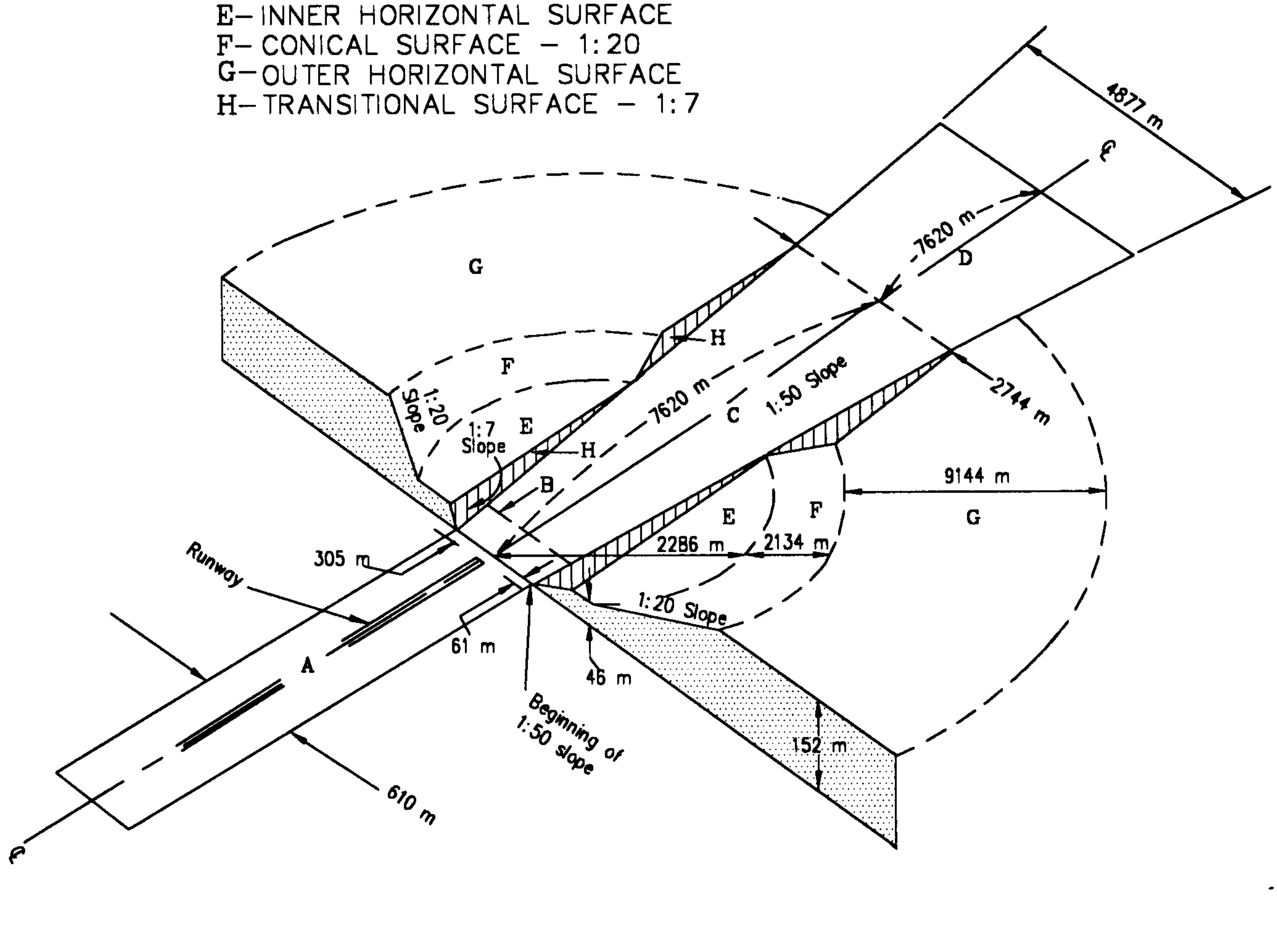
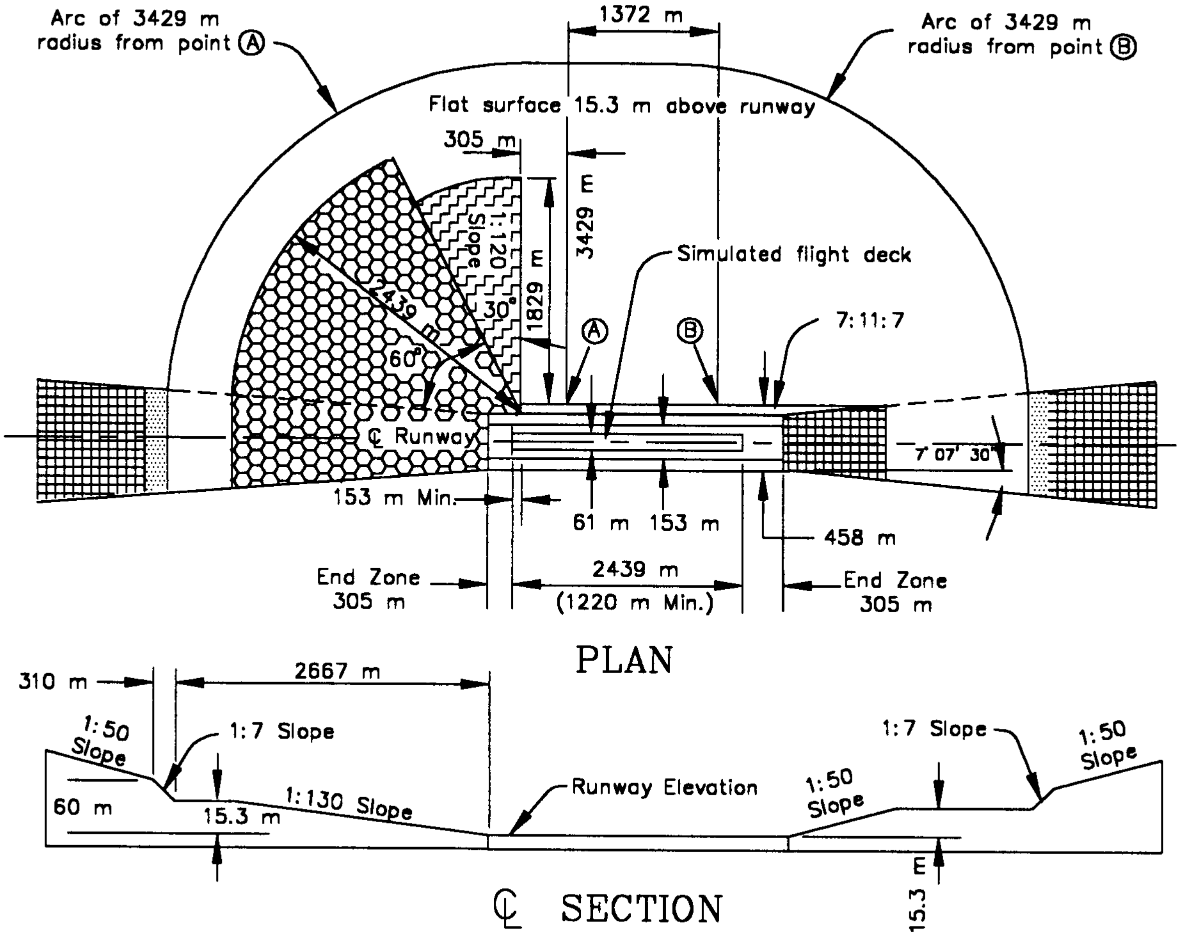
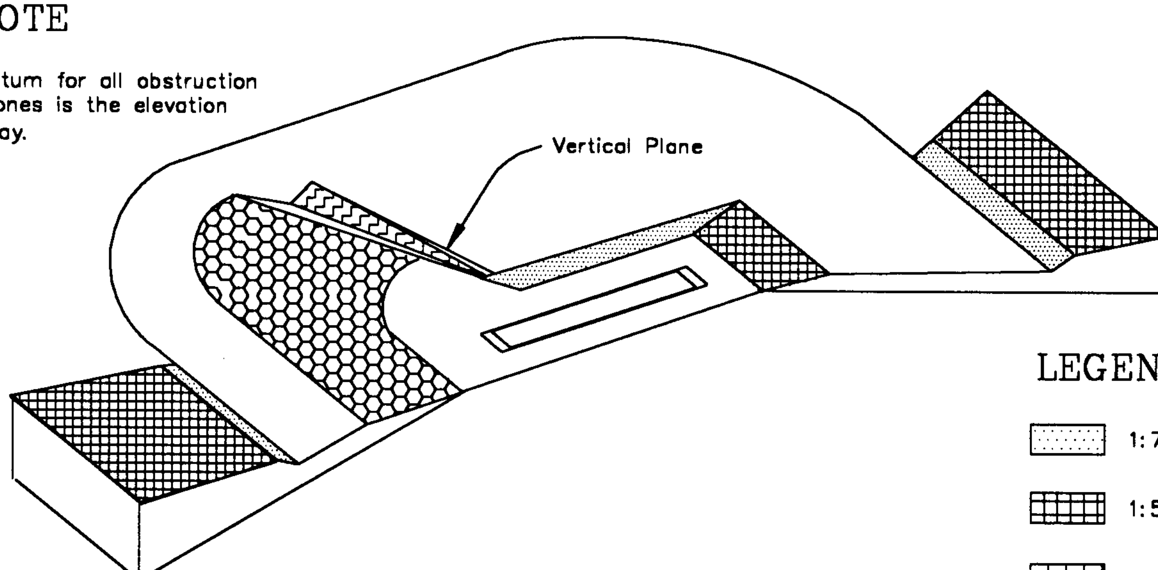


Figure 207.2D
Airway-Highway Clearance Requirements (Navy Carrier Landing Practice Field)



NOTE

Elevation datum for all obstruction clearance zones is the elevation of the runway.



LEGEND

(dotted)	1:7 Slope
(grid)	1:50 Slope
(zigzag)	1:120 Slope
(hexagon)	1:130 Slope

Where it appears that a 2-lane road will be adequate for the foreseeable future, but no right of way width has been established, a minimum span length sufficient for a 12.0 m roadbed should be provided. Additional span length should be provided to permit future sidewalks where there is a foreseeable need. If it is reasonably foreseeable that more than two lanes will be required ultimately, a greater width should be spanned.

(c) For horizontal and vertical clearances, see Topic 309.

208.2 Cross Slope

The crown is normally centered on the bridge except for one-way bridges where a straight cross slope in one direction should be used. The cross slope should be the same as for the approach pavement (see Index 301.2).

208.3 Median

On multilane divided highways a bridge median that is 10.8 m wide or less should be decked. Exceptions require individual analysis. See Chapter 7 of the Traffic Manual for median barrier warrants.

208.4 Bridge Sidewalks

Bridge sidewalks should be provided where justified by pedestrian traffic (see Figure 208.10B).

208.5 Open End Structures

Embankment end slopes at open end structures should be no steeper than 1:1.5 for all highways.

208.6 Pedestrian Overcrossings and Undercrossings

The minimum width of walkway for pedestrian overcrossings should be 2.4 m.

Determination of the width and height of pedestrian undercrossings requires individual analysis to insure adequate visibility through the structure and approaches (see Index 105.2).

Pedestrian ramps should be provided on all pedestrian separation structures. The ramp should have a maximum longitudinal slope of 8.33% with a maximum rise of 760 mm between landings. The landing should be a minimum of 1525 mm in length.

See Topic 309 for vertical clearances.

208.7 Equestrian Undercrossings

Such structures should normally provide a clear opening 3 m high and 3 m wide in cross section. Skewed crossings should be avoided. The structure should be straight so the entire length can be seen from each end.

208.8 Cattle Passes, Equipment, and Deer Crossings

Private cattle passes and equipment crossings may be constructed when economically justified by a right of way appraisal, as outlined in Section 7.09.09.00 of the Right of Way Manual.

The standard cattle pass should consist of either a standard box culvert with an opening 2.4 m wide and 2.4 m high or a metal pipe 3000 mm in diameter. The invert of metal pipe should be paved with concrete or bituminous paving material.

If equestrian traffic is expected to use the culvert a minimum 3 m wide by 3 m high structure may be provided. However, the user of the facility should be contacted to determine the specific requirements.

If conditions indicate a reasonable need for a larger than standard cattle pass, it may be provided if economically justified by the right of way appraisal.

In some cases the installation of equipment or deer crossings is justified on the basis of public interest or need rather than economics. Examples are:

(a) A deer crossing or other structure for environmental protection purposes.

(b) Equipment crossings for the Forest Service or other governmental agencies or as a right of way obligation.

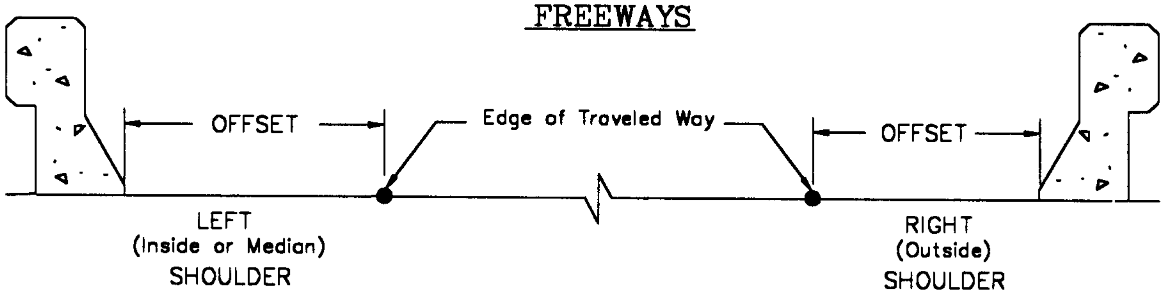
These facilities should be installed where necessary as determined by consultation with the appropriate affected entities.

A clear line of sight should be provided through the structure.

Figure 208.1

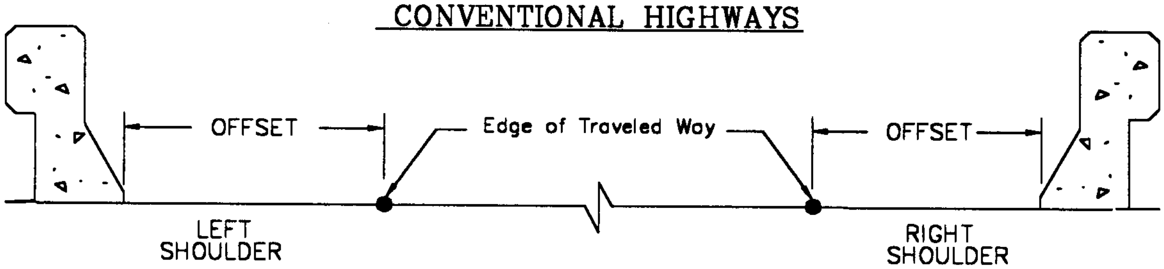
Offsets to Safety-shape Barriers

FREEWAYS



Approach Shoulder Width	Left Shoulder	Right Shoulder
0.6* m & 1.2 m (Ramps)	1.2 m	1.2 m
1.5 m	1.5 m	1.5 m
2.4 m	2.4 m	2.4 m
3.0 m	3.0 m	3.0 m

CONVENTIONAL HIGHWAYS



Approach Shoulder Width	Left Shoulder	Right Shoulder
0.6* m & 1.2 m	1.2 m	1.2 m
2.4 m	2.4 m	2.4 m

* See Index 208.1(1)(b)

208.9 Railroad Underpasses and Overheads

Generally, it is desirable to construct overheads rather than underpasses whenever it is necessary for a highway and railroad to cross. Railroads should be carried over highways only when there is no other reasonable alternative.

Some undesirable features of underpasses are:

(a) They create bottlenecks for railroad operations.

(b) It is difficult to widen the highway.

(c) Pumping plants are often required to drain the highway.

(d) They are likely to lead to cost participation controversies for initial and future construction.

(e) Shooflies (temporary tracks) are generally required during construction.

(f) Railroads are concerned about the structure maintenance and liability costs they incur.

Advantages of overheads are:

(a) Railroads can use most of their right of way for maintenance.

(b) Overheads can be widened at a relatively low cost and with little difficulty.

(c) Less damage may be incurred in the event of a derailment.

(d) Agreements for design and maintenance can be reached more easily with railroads.

(e) Initial costs are generally lower.

The State, the railroads, and the public in general can usually benefit from the construction of an overhead structure rather than an underpass.

See Topic 309 for vertical clearances.

208.10 Bridge Railings

(1) General. There are four classes of railings, each intended to perform a different function.

(a) Vehicular Barrier Railings--The primary function of these railings is to retain and redirect errant vehicles.

(b) Combination Vehicular and Pedestrian Railings--These railings perform the dual function of retaining both vehicles and pedestrians on the bridge. They consist of two parts--A concrete barrier railing with a sidewalk and metal handrailing or fence-type railing.

(c) Pedestrian Railings--These railings prevent pedestrians from accidentally falling from the structure and, in the case of fence-type railing, reduce the risk of objects being dropped on the roadway below. Where the facility is accessible to disabled persons and the profile grade exceeds 5%, a handrail for use by the disabled meeting both the State and Federal regulations must be provided.

(d) Bicycle Railings--These railings retain bicycles and riders on the structure. They may be specifically designed for bicycles, or may be a combination type consisting of a vehicular barrier surmounted by a fence or metal handrail.

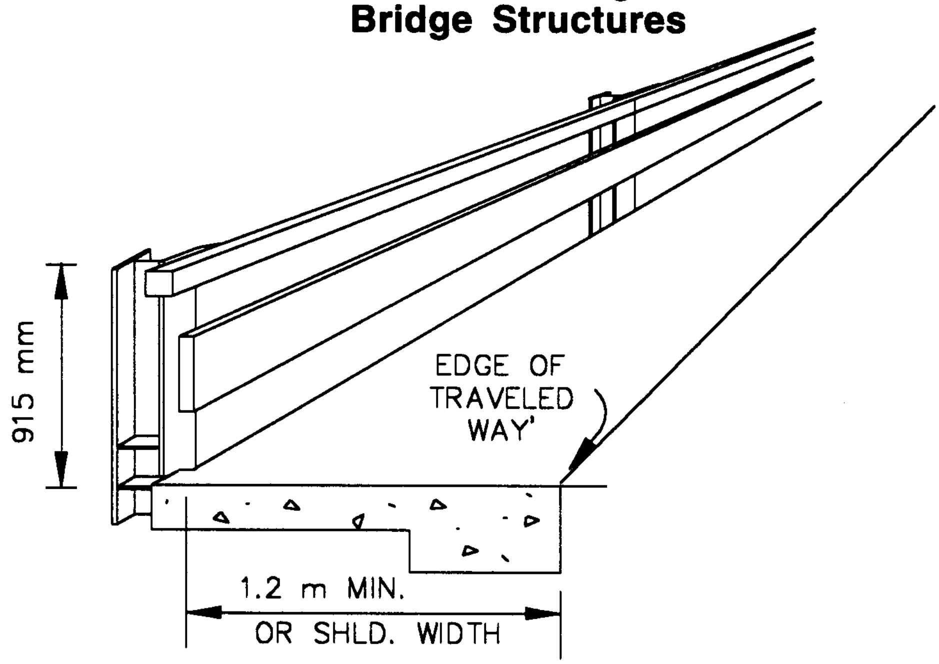
(2) Policies. <u>To reduce the risk of objects being dropped or thrown upon vehicles, protective screening in the form of fence-type railings should be installed along new overcrossing structure sidewalks in urban areas (Sec.92.6 California Streets and Highways Code).</u> Screening should be considered for the opposite side of structures having one sidewalk. Screening should be installed at such other locations determined to be appropriate.

The approved types of railings for use on bridge structures are listed below and illustrated in Figures 208.10A, B, and C. Railing types not listed are no longer in general use; however, they may be specified in those cases where it is desirable to match an existing condition.

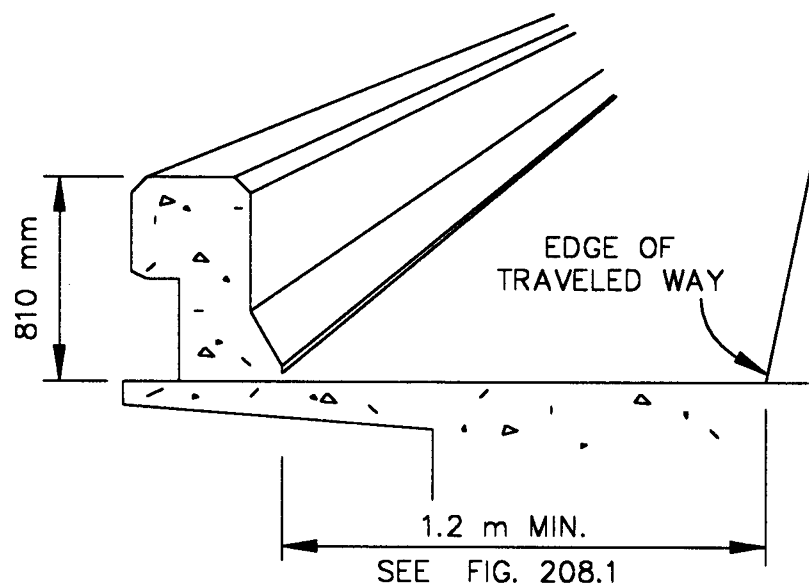
The District should specify in the bridge site data submittal the rail type to be used after consideration has been given to the recommendations of the local agency (where applicable) and the DOS.

Figure 208.10A

Vehicular Railings for Bridge Structures



METAL TUBE RAILING TYPE 18



CONCRETE BARRIER TYPE 25

Figure 208.10B
Combination Railings for Bridge Structures

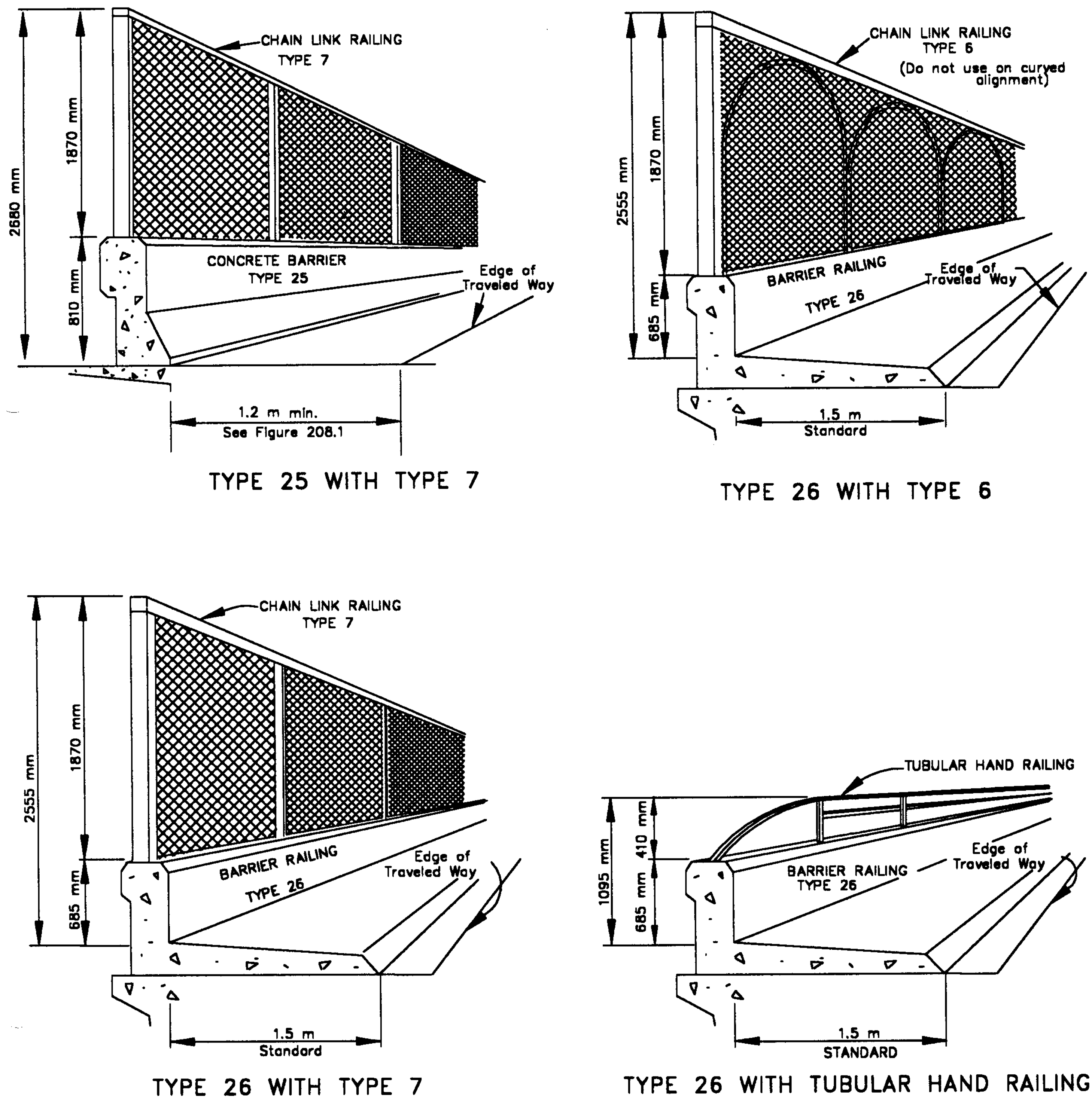
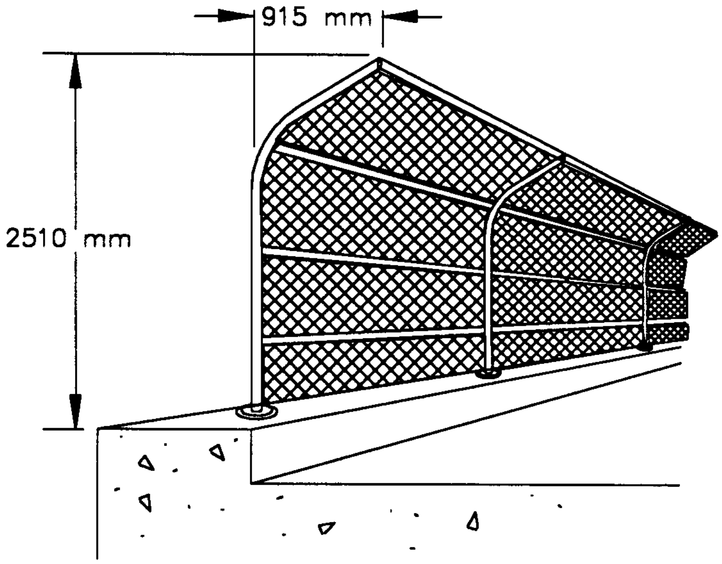
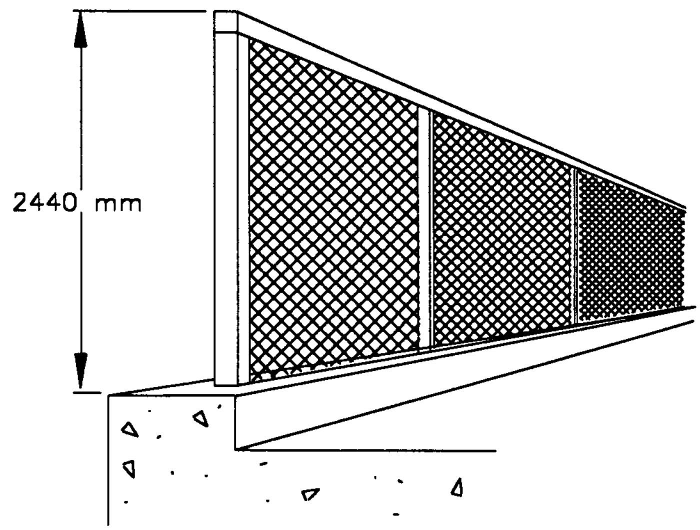


Figure 208.10C

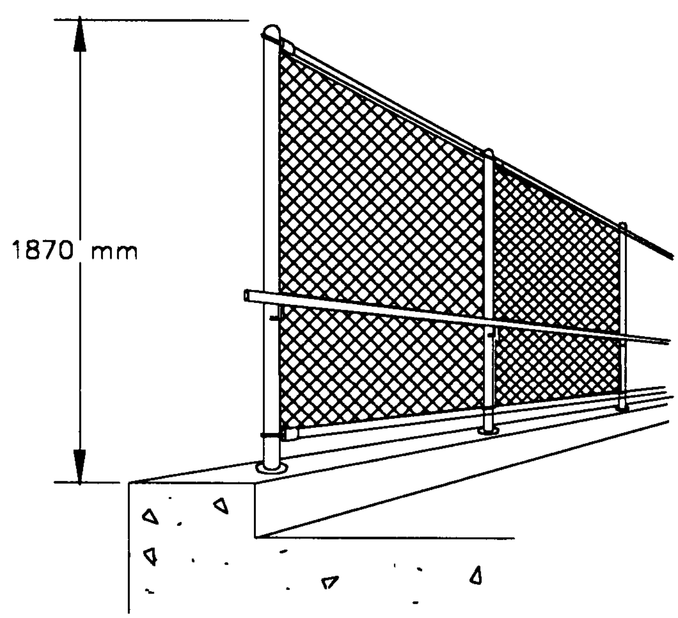
Pedestrian Railings for Bridge Structures



CHAIN LINK RAILING TYPE 3



CHAIN LINK RAILING TYPE 7 (MODIFIED)



CHAIN LINK RAILING (1.8 m)

(3) Vehicular Railings. See Figure 208.10A.

(a) Concrete Barrier Type 25--This is the vehicular barrier for general use adjacent to traffic. Figure 208.1 illustrates the position of the barrier relative to the edge of traveled way.

(b) Metal Tube Railing Type 18--This railing may be used in those situations where a self cleaning deck is preferred, or where more see-through area is desired than is provided by a solid concrete parapet. In general, it should not be used on bridges which cross a lower roadway because of the problem of drainage and debris falling off the side of the bridges. Its use should be limited because of its cost and appearance.

(4) Combination Railings. See Figure 208.10B.

(a) Barrier Railing Type 26--This is the barrier railing for general use when sidewalks are provided on a bridge. It must be accompanied with a tubular handrailing or a fence-type railing. The minimum sidewalk width is 1.5 m, however, this width may be varied as circumstances require.

(b) Chain Link Railing Type 7--This is the fence-type railing for general use with Type 26 barrier railing with sidewalk to reduce the risk of objects being dropped on the roadway below. When a sidewalk (Type 26 railing) is provided on one side of a bridge and Type 25 barrier railing on the other side, Type 7 railing may be placed on top of the Type 25 as additional protection from dropped objects. Consideration should be given to the effect of the Type 7 railing on sight distance at the bridge ends and view over the side of the bridge. Lighting fixtures may be provided with Type 7 railings.

(c) Chain Link Railing Type 6--This railing may be used in lieu of Type 7 when special architectural treatment is required. It should not be used on curved alignment because of fabrication difficulties.

(d) Tubular Handrailing--This railing is used with Type 26 to increase the combined rail height for the safety of pedestrians. It should be used in lieu of Type 7 where object dropping will not be a problem or at the ends of bridges to increase sight distance if fence-type railing would restrict sight distance.

(5) Pedestrian Railings. See Figure 208.10C

(a) Chain Link Railing Type 3--This railing is used on pedestrian structures to reduce the risk of objects being dropped on the roadway below.

(b) Chain Link Railing Type 7 (Modified)--This railing is similar to Type 7 except that it is mounted on the structure at the sidewalk level.

(c) Chain Link Railing (Six-foot)--This railing is not as high as Types 3 or 7 and therefore, its use is restricted to those locations where object dropping or throwing will not be a problem.

(d) Chain Link Railing (Modification)--Existing railing may be modified for screening under the protective screening policy. The DOS should be contacted for details.

(6) Bicycle Railing. The minimum height of bicycle rail is 1.4 m above the deck surface. Pedestrian railings and combination railings consisting of a concrete barrier surmounted by a fence or tubular railing are satisfactory for bicycles, if at least 1.4 m high. Bicycles are not considered to operate on a sidewalk, except in special cases where signs specifically direct cyclists to use the sidewalk.

As a general policy, bicycle railings should be installed at the following locations:

(a) On a Class I bikeway, except that a lower rail may be used if a curbed sidewalk, not signed for bicycle use, separates the bikeway from the rail or a shoulder at least 2.4 m wide exists on the other side of the rail.

(b) On the outside of a Class II or III bikeway, unless a curbed sidewalk, not signed for bicycle use, separates the bikeway from the rail.

(c) In other locations where the designer deems it reasonable and appropriate.

(7) *Bridge Approach Railings.* **Approach railings shall be installed at the ends of bridge railings exposed to approach traffic.**

Refer to Chapter 7 of the Traffic Manual for placement and design criteria of guardrail.

Topic 209 - Curbs and Gutters

209.1 General Policy

As a general policy, construction of curbs and gutters should be limited to those cases where curbs are justified by sound engineering reasons. Reasons for constructing curbs and gutters on State highways include the following:

(a) Where required for proper drainage.

(b) Where needed for channelization, delineation, control of access, or other means of improving traffic flow and safety.

(c) At ramp connections with local streets for the protection of pedestrians and continuity of construction at a local facility.

(d) As a replacement of existing curbs and gutters.

(e) On frontage roads on the side adjacent to the freeway where required for the protection of the freeway fence.

(f) When necessary to conform to local arterial street standards in urban areas.

<u>The use of curbs should be avoided on freeways or other highways with design speeds of 75 km/h and over.</u>

209.2 Types and Uses

The curb sections illustrated on the Standard Plans are approved types to be used as stated below.

(1) *Type A Curbs.* These are commonly called "barrier curbs", but they do not constitute a positive barrier as they are easily mounted except at low speeds and flat angles of approach. Their main functions are to deter vehicles from using areas outside the traveled way not intended for vehicular travel, to control drainage, and to control parking of vehicles.

Types A1-150 and A2-150 are 150 mm high. Typical uses are adjacent to sidewalks and parking lanes.

Types A1-200 and A2-200 are 200 mm high. They may be used in lieu of 150 mm curbs when requested by local authorities if the curb criteria stated under Index 209.1 are satisfied. Typical uses of these curbs are at the edge of frontage roads adjacent to the freeway.

(2) *Type B Curbs.* Type B curbs are called "deterring curbs". Since all have a 1.5:1 slope on the face, they are mounted more easily than Type A curbs.

Types B1, B2, and B3 are 150 mm high. Typical uses of these curbs are for drainage control and channelization.

Type B4 is 80 mm high and is typically used for: median openings (see Index 209.3), channelization, and special uses described under Index 504.8(7). This curb is not considered adequate for drainage control.

(3) *Type E Curb.* This essentially is a rolled gutter used only in special drainage situations, for example: where drainage parallels and flows against the face of a retaining wall.

(4) *Type H Curb.* This type may be used on bridges where it is desired to match the approach roadway curb.

209.3 Position of Curbs

The general policy for positioning curbs is to provide the same unobstructed roadbed width at intersections and median openings as is normally provided between such points. All dimensions (offsets) to curbs are from the near edge of traveled way to the inside face of curb at gutter grade.

(1) *Through Lanes.* Minimum curb offsets, right and left, should be the normal width of the outside (right) and inside (median) shoulder, respectively, as set forth in Table 302.1.

(2) *Channelization.* Island curbs used to channelize intersection traffic movements should be positioned as described in Index 405.4.

(3) *Separate Turning Lanes.* Curb offsets to the right of right turn lanes in urban areas may be reduced to 0.6 m if bicycle traffic is not a consideration and design exception approval has been obtained in accordance with Index 82.2. No curb offset is required to the left of left turn lanes in urban areas.

(4) *Median Openings.* Median openings (Figure 405.5) should not be curbed unless necessary to delineate areas occupied by traffic signal posts. Mountable B4 curbs should be used in these special cases.

(5) *Urban Arterial Highways*. Continuous median curb offsets may be reduced to 0.6 m when necessary to match local agency standards on conventional divided highways in urban areas when design speed is equal to or less than 75 km/h.

209.4 Curbs on Frontage Roads and Streets

Continuous curbs are not necessarily required on all frontage roads. Where curbs are necessary for drainage control or other reasons, they should be Type A and placed as shown on Figure 307.4. Consideration may be given to the use of local curb standards where such request is made by local authorities. Type B curbs are not considered suitable side curbs for frontage roads or city streets (see Index 209.1).

209.5 Curbs for Bridges and Grade Separation Structures

When both roadbeds of a curbed divided highway are carried across a single structure, the median curbs should be in the same location as on the adjacent roadways.

209.6 Gutter Cross Slopes

When the pavement drains toward the curb, the cross slope of gutters normally should be 8% toward the curb. Pavement slopes on superelevated roadways extend the full width of the gutter, except that gutter slopes on the low side should not be less than 8% (see Index 836.2 for principles of gutter design).

Topic 210 - Earth Retaining Systems

210.1 Types and Uses

Earth retaining systems can be divided into five categories:

- State designed systems which involve a Standard Plan,
- State designed systems which require a special design,
- Proprietary systems which have been pre-approved by DOS for listing in Special Provisions for specific projects.
- Proprietary systems which are awaiting DOS approval.
- Experimental systems.

(1) *State Designed Earth Retaining Systems With Standard Plans.* Standard Plans are available for a variety of earth retaining systems (retaining walls). Loading conditions and foundation requirements are outlined in the Standard Plans. For sites with requirements that are not covered by the Standard Plans, a special design earth retaining system is required. To assure conformance with the Standard Plan requirements and, therefore, completion of the PS&E in a timely fashion, design engineers should request a foundation investigation for all locations at which a retaining wall is being considered. Retaining walls which have Standard Plans are as follows:

(a) Retaining Wall Types 1 and 2 (Concrete Cantilever). These walls have standard design heights up to 10 900 mm, but are most economical below 6000 mm. Concrete cantilever walls accommodate traffic barriers, sound walls, and drainage facilities efficiently.

(b) Retaining Wall Type 3 and 4 (Concrete Counterfort). These walls may be used where minimum wall deflection is desired. When used in conjunction with concrete cantilever walls, there should be an offset in the plane of the wall faces to mask the difference in deflection between the two wall types. The cost of these walls is generally more than for concrete cantilever walls of similar height.

(c) Retaining Wall Type 5 (Concrete L-Type Cantilever). Although more costly than cantilever walls, these walls may be required where site restrictions do not allow for a footing projection beyond the face of the wall stem.

(d) Retaining Wall Type 6 (Concrete Masonry Walls). These walls may be used where the design height of the wall does not exceed 1800 mm. These walls are generally less costly than all other standard design walls or gravity walls. Where traffic is adjacent to the top of the wall, guardrail should be set back as noted in the Standard Plans.

(e) Crib Walls. The following types are available:

- Concrete Crib Wall - This type of crib wall may be used for design heights up to 16 000 mm. Concrete crib walls are suited to coastal areas and higher elevations where salt air and deicing salts may limit the service life of other types of crib walls. Concrete crib walls may be closed face and, therefore, useful where impinging flow is a problem.

- Steel Crib Wall - This type of crib wall may be used for design heights up to 10 900 mm. Steel crib walls are light in weight; easily transported and installed; and, therefore, suited for relatively inaccessible installations and for emergency repairs.

- Timber Crib Wall - This type of crib wall may be used for design heights up to 6600 mm. Timber crib walls have a rustic appearance which makes them suited to a rural environment. When all of the wood members are pressure preservative treated, the service life of timber crib walls is comparable to that of concrete or steel crib walls.

Timber and concrete crib walls constructed on horizontal alignments with curves or angle points require special details, particularly when the wall face is battered. Because crib wall faces can be climbed, they are not recommended for urban sites where they will be accessible to the public. The economical height for all crib walls is generally less than 9000 mm.

(2) *State Designed Earth Retaining Systems Which Require Special Designs.* Some sites require a special design earth retaining system to accommodate existing and future ground contours, traffic, utilities or other constructed features, site geology, economy, or aesthetics.

Some special design earth retaining systems are as follows:

(a) Standard Plan Walls. The design loadings, heights, and types of walls in the Standard Plans cover frequent applications for earth retaining systems. However, special designs are necessary if the imposed loading exceeds that in the Standard Plans. Railroad live load; building surcharge; loads imposed by sign structures, electroliers, or sound walls are examples. Foundation conditions that require pile support for the wall necessitates a special design. Design is by the DOS.

(b) Bulkheads. These systems are also referred to as cantilevered pile, sheet pile, tied-back, anchored pile, or soldier pile walls. These walls are most practical in cut sections and are best suited for situations where excavation for a retaining wall with a footing is impractical because of traffic, utilities, existing buildings, or right of way restrictions. In embankment sections, a bulkhead wall is a practical solution for a roadway widening where design heights are less that 1800 mm. They are also practical for slip-out corrections. Bulkheads can consist of either concrete, steel, or timber sheet piles, or concrete, steel or timber soldier piles either driven or placed in drilled holes and backfilled, with either concrete facing or lagging or timber lagging. Bulkhead walls can be either cantilevered or anchored with tie rod and deadman anchors, ground anchors, or rock anchors. The method of support and anchorage depends on site conditions, design height, and loading imposed. The cost of these walls is variable depending on earth retaining requirements, site geology, aesthetic consideration, and site restraints. Design is by DOS.

(c) Concrete or Rock Gravity Walls. These walls are most economical at design heights below 1200 mm. They are constructed at heights between 1200 mm and 1800 mm only for short lengths, and then only if considerable length of the shorter height is involved. These walls can be used in connection with a cantilever wall if long lengths of wall with design heights of less than 1200 mm are required. A Type 50C concrete barrier, which can be found in the Standard Plans, can serve as a gravity retaining wall in locations where a differential in height of up to 900 mm exists between adjoining roadway grades. Design is by DOS.

(d) Soil Reinforcement Systems. Soil reinforcement systems consist of facing elements and soil reinforcing elements incorporated into a compacted or in situ soil mass. The reinforced soil mass functions similar to a gravity wall.

Soil reinforcing elements can be any material that provides tensile strength and pullout resistance, and possesses satisfactory creep characteristics and service life. Generally, reinforcing elements are steel, but polymeric and fiberglass systems may be used.

Facing elements for most systems are either reinforced concrete, light guage steel, or treated wood. Polymeric walls may be faced with masonry-like elements or even planted with local grasses. Selection of facing type is governed by aesthetics and service life.

Wall heights of soil reinforcement systems are controlled mainly by bearing capacity of the foundation material and global stability of the site. Wall heights in excess of 18 000 mm are feasible where conditions permit. Foundation investigations for soil reinforcement systems are similar to investigations for conventional retaining walls.

Special details are required when a soil reinforcement system must accommodate drainage structures, overhead sign supports or sound walls on piles within the reinforced soil mass. Concrete traffic barriers require a special design support slab when used at the top of the facing of these systems. These systems can not be used where site restrictions do not allow necessary excavation or placement of the soil reinforcing elements.

Soil reinforcement systems can be classified within two categories typified by the method of construction:

- "Bottom Up Methods" - These soil reinforcement systems involve the placement of reinforcement during construction of an embankment. When conditions permit their use, these systems are generally the most economical choice for wall heights greater than 6000 mm. They may also be the most economical system for wall heights in the 3000 mm to 6000 mm range, depending on specific project requirements.

  Because of the articulated nature of the facing elements these systems use, they can tolerate greater differential settlement than can conventional concrete retaining walls.

  Steel elements used in this method are sized to provide sacrificial steel to offset corrosion; and, additionally, are galvanized for permanent installations.

- "Top Down Methods" - At the time of this revision, soil nailing is the only method of reinforcing undisturbed earth during excavation of a cut slope practiced by Caltrans. This system involves insertion of reinforcement "soil nails" at an angle into undisturbed in situ material during excavation. When site conditions permit its use, soil nailing will generally be the most economic system for all heights.

  Because soil nailing is accomplished concurrent with excavation, and thus results in an unloading of the foundation, there is generally no significant differential movement.

  Steel "soil nails" used in this method are protected against corrosion either by being epoxy coated or encapsulated within a grout filled corrugated plastic sheath, and surrounded by portland cement grout placed during construction.

  Soil reinforcement systems are designed by both the state and private firms. Vendor systems are termed "proprietary" and are listed in paragraphs (3) and (4) of this section. Some state designed soil reinforcement systems that require special design are as follows:

- Mechanically Stabilized Embankment (MSE) - This system was developed by the Roadway Geotechnical Engineering Branch of the Office of Structural Foundations and uses galvanized welded wire mats as soil reinforcing elements. The facing elements are precast concrete. In many cases, this system can be constructed using on-site backfill materials. Design by DOS.

- Salvaged Material Retaining Wall - This system was developed by the Roadway Geotechnical Engineering Branch of the Office of Structural Foundations and utilizes C-channel sections as soil reinforcement. Galvanized metal beamguard rail, timber posts or concrete panels are used as facing elements. Often the materials involved can be salvaged from state rehabilitation projects. The District Recycle Coordinator should be consulted as to availability of salvaged materials. Design by the Roadway Geotechnical Engineering Branch of the Office of Structural Foundations.

- Soil Nail Wall - This system reinforces either original ground or an existing embankment during the excavation process. Soil nailing is always accomplished from the top down in stages that are typically 1200 mm to 1800 mm in height. After each stage of excavation, corrosion protected soil reinforcing elements, "soil nails", are placed and grouted into holes which have been drilled at angles into the in situ material. The face of each stage of excavation is protected by a layer of reinforced shotcrete. After the full height of wall has been excavated and reinforced, a finish layer of concrete facing is placed either by the shotcreting method or by casting within a face form. Design by DOS.

- Tire Anchor Timber (TAT) Wall - This system was developed by the Roadway Geotechnical Engineering Branch of the Office of Structural Foundations and utilizes steel bars with used tire side walls attached by cross bars as soil reinforcing elements. The facing elements are treated timber. TAT walls have a rustic appearance which makes them suited to a rural environment. Design by the Roadway Geotechnical Engineering Branch of the Office of Structural Foundations.

(3) *Proprietary Earth Retaining Systems (Pre-Approved).* These conventional retaining walls, cribwalls, and soil reinforcement systems are designed, manufactured, and marketed by a vendor. These systems are

termed proprietary because most of these systems are patented. Pre-approval status means that these systems may be listed in the Special Provisions of the project as an Alternative Earth Retaining System (AERS) when considered appropriate for a particular location. For a proprietary system to be given pre-approval status, the vendor must submit standard plans and design calculations to DOS for their review and approval. Preapproved proprietary earth retaining systems are as follows:

(a) Reinforced Earth (RE). This French, patented soil reinforcement system is marketed by the Reinforced Earth Company. Reinforced Earth utilizes steel strips as soil reinforcing elements and precast concrete face panels.

(b) Reinforced Soil Embankment (RSE). This patented soil reinforcement system is marketed by The Hilfiker Company. RSE walls utilize welded wire mat soil reinforcement and precast concrete face panels.

(c) Welded Wire Walls. This patented soil reinforcement system is marketed by The Hilfiker Company. Welded Wire Walls are constructed using welded wire mat units which are both the soil reinforcement and the facing element.

(d) Retained Earth (VSL) Walls. This patented soil reinforcement system is marketed by the VSL Corporation. Like MSE walls, retained earth walls use welded wire mat soil reinforcement and precast concrete face panels.

(e) Criblock Walls. This patented concrete cribwall system is marketed by Retaining Walls Company.

(f) Port-O-Wall. This system is marketed by Port-O-Wall Enterprises. This system consists of cantilevered precast concrete stem panels supported by a cast-in-place concrete footing.

It should be noted that this list includes only those systems which were pre-approved by DOS at the time of this revision. New systems will be added to the list as they are submitted, evaluated, and approved.

(4) *Proprietary Earth Retaining Systems (Pending).* The systems in this category have been submitted by a vendor to the DOS for evaluation. They will undergo thorough review and any necessary testing and with the approval of DOS, they will be added to the list of pre-approved proprietary earth retaining systems and can be listed in the Special Provisions under Alternative Earth Retaining Systems.

In most cases, proprietary systems will be listed in the Special Provisions for a project under Alternative Earth Retaining Systems. However, if a proprietary system is the only retaining system deemed appropriate for a project and, therefore, the only system contained in the project documents, the construction of that system must be designated experimental construction in accordance with existing contract agreements concerning sole source purchases.

(5) *Experimental State Designed Earth Retaining Systems*. Every earth retaining system must undergo a thorough evaluation before becoming accepted for routine use. Newly introduced designs or untried combinations of proprietary and non-proprietary designs or products are, therefore, considered experimental. Evaluation of the system may take the form of either a Category 1 or a Category 2 Experimental Construction Project. Category 1 projects are administered by either the Office of Structural Foundations or DOS. Category 2 projects are administered through the Office of Engineering Services, Value Analysis and Resource Conservation Branch, and require a minimum of paperwork. The evaluation process in both cases is federally funded. Once a system has been evaluated the experimental status will be changed.

Some earth retaining systems which are considered experimental are as follows:

(a) Fabric or Plastic Reinforced Walls. These systems utilize geotextiles or plastics as the soil reinforcing elements. The face of these walls can be left exposed if the fabric has been treated to prevent decay from ultra-violet rays. Concrete panels, mortarless masonry, tar emulsion, or air blown mortar may be used as facing materials or the face may be seeded if a more aesthetic treatment is preferred. Design is by the Office of Structural Foundations.

(b) Mortarless Masonry Gravity Walls. Each of these systems utilizes the friction and shear developed between facing units and the combined weight of the units to retain the backfill. Some of these systems have been used as erosion protection at abutments and on embankments. They can be used as an aesthetic treatment for facing fabric and plastic soil reinforced walls. All of these systems require a batter. Design is by the Office of Structural Foundations.

It should be noted that this list includes only those systems which are being evaluated by the Office of Structural Foundations at the time of this revision. New systems will be added to the list as they are considered.

210.2 Alternative Earth Retaining Systems (AERS)

The Alternative Earth Retaining Systems procedure encourages competitive bidding and potentially results in cost savings. Therefore, AERS should be considered in preparing all project documents involving earth retaining systems.

DOS initiated the AERS procedure in 1982. Implementation of the procedure means that various earth retaining systems are presented in the contract bid package and are, therefore, able to be considered for use by a contractor. Under this procedure, a fully detailed State designed earth retaining system will be provided for each location, and will be used as the basis for payment. Additional systems may be presented in the contract documents as alternatives to the fully detailed State design and can be considered for use at specified locations. The fully detailed State designed earth retaining system which is used as the basis for payment may be either a Standard Plan system or a special design system. Additional (or alternative) systems may be State designed systems, pre-approved proprietary systems, an experimental system, or any combination thereof. The State designed alternative systems, both Standard Plan walls and special design systems, will be fully detailed on the plans. The alternative systems which are pre-approved proprietary systems will be listed in the Special Provisions as Alternative Earth Retaining Systems.

Implementation of the AERS process requires the involvement of the District Design Engineer, DOS, and the Office of Structural Foundations. The District Design Engineer should submit pertinent site information (site plans, typical sections, etc.) to both the Office of Structural Foundations and DOS for feasibility studies as early as possible in the project design stage.

Under the AERS procedure, parts of the PS&E package which pertain to the earth retaining systems will be prepared as follows:

- Project plans for the State designed systems can be prepared by the District Design Engineer (Standard Plan systems), the Office of Structural Foundations (special design soil reinforcement systems and experimental systems), or DOS (Standard Plan systems and special design systems).

- Pre-approved proprietary systems will be listed in the Special Provisions.

- Specifications and Estimates for the fully detailed State designed system, which will be used as the basis for payment, will be prepared by DOS.

The earth retaining systems under this procedure will be measured and paid for by the square meter area of the face of the earth retaining system which has been indicated to be the basis of payment. Should an Alternative Earth Retaining System be constructed, payment will be made based on the measurements of the State designed system which was designated as basis of payment. The contract price paid per square meter is for all items of work involved and includes excavation, backfill, drainage system, reinforcing steel, concrete, soil reinforcement, and facing. Any barrier, fence, or railing involved is measured and paid for as separate items.

210.3 Cost Reduction Incentive Proposals (CRIP)

The contractor may submit a proposal for an earth retaining system under Section 5-1.14 of the Standard Specifications, Cost Reduction Incentive. The proposed system may modify or replace the earth retaining system permitted by the contract. This gives vendors of proprietary earth retaining systems a method for having their system used prior to having pre-approval of a standard plan submittal for that system. CRIP submittals are administered by the Resident Engineer. Contract Change Orders are not to be processed until the CRIP is approved by Headquarters Construction with review assistance provided by other functional units.

210.4 Aesthetic Consideration

The profile of the top of wall should be designed to be as pleasing as the site conditions permit. All changes in the slope at the top of cast-in-place concrete walls should be rounded with vertical curves at least 6000 mm long. Small dips in the top of the wall should be eliminated. Sharp dips should be improved by using vertical curves, slopes, steps, or combinations thereof. Side slopes may be flattened or other adjustments made to provide a pleasing profile.

Where walls are highly visible, special surface treatment or provisions for landscaping should be considered. Aesthetic treatment of walls should be referred to DOS for study by the Transportation Architecture Branch.

Walls should not have indentations or protrusions less than 1800 mm above grade large enough to snag errant vehicles.

When alternative wall types are provided on projects with more than one wall site, any restriction as to the combination of wall types should be specified in the Special Provisions.

210.5 Safety Railing, Fences, and Concrete Barriers

Cable railing should be installed for employee protection in areas where employees may work adjacent to and above vertical faces of retaining walls, wingwalls, abutments, etc. where the vertical fall is 750 mm or more.

If cable railing is required on a wall which is less than 1370 mm tall and that wall is located within the clear recovery zone, then the cable railing should be placed behind the wall. See Standard Plans for details of cable railing.

Special designs for safety railing may be considered where aesthetic values of the area warrant special treatment.

Concrete barriers may be mounted on top of retaining walls. Details for concrete barriers mounted on top of retaining walls Type 1 through 5 are shown in the Standard Plans. A special design traffic slab is required if a concrete barrier is to be used at the top of crib walls and most special design earth retaining systems. DOS should be contacted for preparation of the plans involved in the special design.

Retaining walls joining right of way fences should be a minimum of 1800 mm clear height.

210.6 Design Responsibility

DOS has primary responsibility for the structural design and preparation of the contract documents (PS&E) for earth retaining systems in the Standard Plans and for the special designs involving bulkheads, concrete and rock gravity walls, pile support systems, Mechanically Stabilized Embankment, and soil nail walls. The Roadway Geotechnical Engineering Branch of the Office of Structural Foundations has primary responsibility for the geotechnical design of soil nail walls. DOS prepares the Specifications and Engineer's Estimate for contracts where the Alternative Earth Retaining Systems (AERS) procedure is used. DOS reviews and approves standard plan submittals for proprietary earth retaining systems submitted by vendors. DOS and the Roadway Geotechnical Engineering Branch of the Office of Structural Foundations assist Headquarters Construction in evaluating the Cost Reduction Incentive Proposals (CRIP) submitted by contractors.

Districts may prepare contract plans, specifications, and engineer's estimate for Standard Plan retaining walls provided the foundation conditions and site requirements permit their use. A foundation investigation is required for all earth retaining structures. Project plans, specifications, and estimates for Tire Anchored

Timber walls, Salvaged Material walls, and experimental walls will be prepared by the Districts with the assistance of the Roadway Geotechnical Engineering Branch of the Office of Structural Foundations. Earth retaining systems can be included in the PS&E as either Highway or Structure items.

Requests for the special design of a retaining system should be submitted at least 6 months before the PS&E is due. At least 2 months is required to conduct a foundation investigation for a retaining structure. A site plan, index map, cross sections, vertical and horizontal alignment, and utility and drainage requirements should be sent along with the request.

The ESC Office of Structural Foundations has responsibility for making foundation recommendations for all earth retaining systems. They assist the District Design Engineer with preparation of contract documents for special designs of Tire Anchor Timber walls, Salvage Material walls, and experimental earth retaining systems.

Both the Office of Structural Foundations and the DOS have responsibility for making feasibility studies for Alternative Earth Retaining Systems. The District should submit project site information (site plans, typical sections, etc.) to both of them as early in the planning stages as possible so that determination of the most appropriate earth retaining systems to use can be made.

210.7 Guidelines for Plan Preparation

(1) *Type Selection.* Wall type selection should be based on considerations set forth in Index 210.1. Both State designed earth retaining systems and proprietary earth retaining systems may meet the requirements for a project. Therefore, to promote competitive bidding which can result in cost savings, all appropriate earth retaining systems should be included in the contract documents.

(2) *Foundation Investigations.* A foundation investigation should be requested from the ESC Office of Structural Foundations for all sites involving an earth retaining system. All log of test boring sheets accompanying the foundation reports must be included with the contract plans.

The following guidelines should be used to prepare the contract plans for earth retaining systems which are found in the Standard Plans:

(a) Loads. All wall types selected must be capable of supporting the field surcharge conditions. The design surcharges can be found in the Standard Plans. Deviance from these loadings will require a special design.

(b) Footing Steps. For economy and ease of construction of wall Types 1 through 6, the following criteria should be used for layout of footing steps.

- Distance between steps should be in multiples of 2400 mm.
- A minimum number of steps should be used even if a slightly higher wall is necessary. Small steps, less than 300 mm in height, should be avoided unless the distance between steps is 29 200 mm or more. The maximum height of steps should be held to 1200 mm. If the footing thickness changes between steps, the bottom of footing elevation should be adjusted so that the top of footing remains at the same elevation.

(c) Sloping Footings. The following criteria should be used for layout of sloping footings.

- The maximum permissible slope for reinforced concrete retaining walls is 3%. Maximum footing slope for masonry walls is 2%.
- When sloping footings are used, form and joint lines are permitted to be perpendicular and parallel to the footing for ease of construction.
- In cases where vertical electroliers or fence posts are required on top of a wall, the form and joint lines must also be vertical. A sloping footing should not be used in this situation since efficiency of construction would be lost.

- Sloping footing grades should be constant for the entire length of the wall. Breaks in footing grade will complicate forming and result in loss of economy. If breaks in footing grade are necessary, a level stepped footing should be used for the entire wall.

- When the top of wall profile of crib walls is constant for the entire length, the bottom of wall profile may be sloped to avoid steps in the top of wall. In this case, all steps to compensate for changes of wall height and original ground profile would be made in the bottom of wall. The maximum permissible slope is 6%. If vertical electroliers or fence posts are required on top of the wall, the crib wall should not be sloped. Sloping crib walls are permissible with guard railing with vertical posts.

(d) Wall Joints. General details for required wall joints on wall Types 1, 1A, 2, and 5 are shown on Standard Plan B0-3. Expansion joints, Bridge Detail 3-3, should be shown at maximum intervals of 29 200 mm. Shorter spaces should be in multiples of 2400 mm. Expansion joints should not be placed near an angle point in the wall alignment. When concrete barriers are used on top of retaining walls, the waterstop in the expansion joint must be extended 150 mm into the barrier. This detail should be shown or noted on the wall plans. Weakened plane joints, Bridge Detail 3-2, should be shown at nearly equal spaces between joints.

(e) Drainage. Gutters should be used behind walls in areas where it is necessary to carry off surface water or to prevent scour. Low points in wall vertical alignment or areas between return walls must be drained by downspouts passing through the walls. Standard Plan B3-9 shows typical drainage details. Special design of surface water drainage facilities may be necessary depending on the amount of surface water anticipated. Where ground water is likely to occur in any quantity, special provisions must be made to intercept the flow to prevent inundation of the backfill and unsightly continuous flow through weep holes.

(f) Quantities. When the AERS procedure is not implemented, wall quantities for each item of work are usually set up for payment. The quantities for concrete and reinforcing steel shown on the Standard Plan sheets do not include any portion of the wall stem above the gutter elevation or toe of slope intersection. Quantities for expansion joint waterstop, structure excavation, structure backfill, pervious backfill material, concrete barrier or railing, and gutter concrete must be tabulated also. Quantities should be tabulated on the plans for each wall.

The following guidelines should be used to prepare the contract plans for soil reinforcement systems:

(a) Leveling Slabs. Most soil reinforcement systems do not require extensive foundation preparation. It may be necessary, however, to design a concrete leveling slab on which to construct the face elements. A reinforced concrete slab will be required in areas prone to consolidation or frost disturbance.

- Steps in the leveling slab should be the same height as the height of the facing elements or thickness of the soil layer between the soil reinforcement.

- Distance between steps in the leveling slabs should be in increments equivalent to the length of individual facing elements.

- A minimum number of steps should be used even if a slightly higher wall is necessary.

(b) Drainage. Gutters should be used behind walls in areas where it is necessary to carry off surface water or to prevent scour. Low points in wall vertical alignment or areas between return walls must be drained by downspouts passing through the walls. Special design of surface water drainage facilities will be necessary and should be prepared by DOS. Where ground water is likely to occur in any quantity, special provisions must be made to intercept the flow to prevent inundation of the backfill.

(c) Quantities. When the AERS procedure is not implemented, quantities for each item of work are usually set up for payment. Bid items must include, but not be limited to: excavation and backfill for the embedment depth, soil reinforcement, facing elements, and concrete for slab construction. Additional bid items for inclusion are any drainage system, pervious backfill, concrete barrier, railings, and concrete gutters. Quantities should be tabulated on the plans for each wall.

The following miscellaneous details are applicable to all earth retaining systems:

(a) Utilities. Provisions must be made to relocate or otherwise accommodate utilities conflicting with the retaining wall. A utility opening for a Type 1 wall is shown in the Standard Plans. Any other utility openings will require special design details and should be reviewed by DOS.

(b) Electroliers and Signs. Details for mounting electroliers and signs on earth retaining systems are designed by DOS. Requests for preparation of details should be made at least 3 months in advance of PS&E. To accommodate the base plates for overhead signs, a local enlargement may affect the horizontal clearance to both the edge of pavement and the right of way line. The enlargement should be considered at the time of establishing the wall layout. For mounting details, furnish DOS a complete cross section of the roadway at the sign and the layout and profile of the earth retaining system.

(c) Fence and Railing Post Pockets. Post pocket details shown for cable railing in the Standard Plans may also be used for mounting chain link fence on top of retaining walls. Special details may be necessary to accommodate the reinforcement in soil reinforcement systems.

(d) Return Walls. Return walls should be considered for use on the ends of the walls to provide a finished appearance. Return walls are necessary when wall offsets are used or when the top of wall is stepped. Return walls for soil reinforcement systems will require special designs to accommodate the overlapping of reinforcing elements.

All special wall details such as sign bases, utility openings, drainage features, fences, and concrete barriers should be shown on the plan sheet of the wall concerned or included on a separate sheet with the wall plan sheets. As a minimum, these details should be cross referenced on the wall sheets to the sheets on which they are shown.